

Union Pacific Railroad Company,
Daniel C. Helix, Mary Lou Helix,
Elizabeth Young, John V. Hook,
Steven Pucell, Nancy Ellicock,
and the Contra Costa County Redevelopment Agency

Feasibility Study

Hookston Station

Pleasant Hill, California

10 July 2006

Environmental Resources Management
1777 Botelho Drive, Suite 260
Walnut Creek, CA 94596

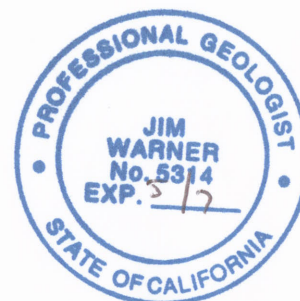
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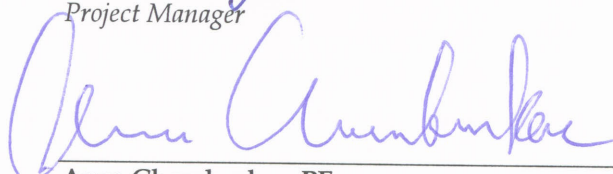
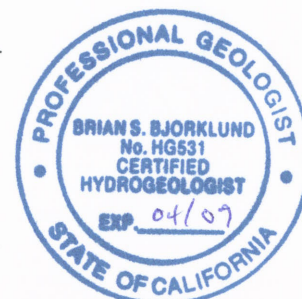
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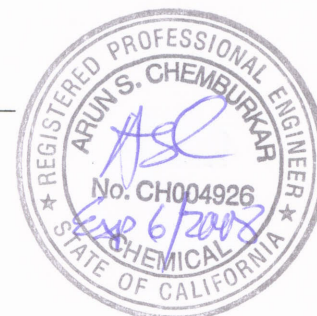
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TABLES OF CONTENTS

LIST OF FIGURES	VI
LIST OF TABLES	IX
LIST OF APPENDICES	XI
LIST OF ACRONYMS	XII
EXECUTIVE SUMMARY	ES-1
1.0 INTRODUCTION	1
1.1 REPORT ORGANIZATION	1
1.2 PURPOSE OF REPORT	3
1.3 BACKGROUND	4
1.3.1 <i>Hookston Station Parcel Location and Physical Description</i>	4
1.3.2 <i>Historical and Current Uses of the Hookston Station Parcel</i>	5
1.3.3 <i>Surrounding Land Use</i>	6
1.3.4 <i>Beneficial Uses of Ground Water and Surface Water</i>	6
1.3.5 <i>Hookston Station Parcel Regulatory Background</i>	7
1.3.6 <i>Adjacent Environmental Sites</i>	9
2.0 SUMMARY OF REMEDIAL INVESTIGATION AND HEALTH RISK ASSESSMENT	11
2.1 REMEDIAL INVESTIGATION SUMMARY	11
2.1.1 <i>Field Investigation Activities</i>	12
2.1.2 <i>Geology and Hydrogeology</i>	13
2.1.3 <i>Chemical Occurrence in Soil</i>	15
2.1.4 <i>Chemical Occurrence in Soil Vapor</i>	16
2.1.5 <i>Chemical Occurrence in Ground Water</i>	17
2.1.6 <i>Chemical Occurrence in Surface Water and Sediment</i>	18
2.1.7 <i>Chemical Occurrence in Indoor Air</i>	19
2.2 REGIONAL GROUND WATER QUALITY	21
2.3 RISK ASSESSMENT SUMMARY	22

2.3.1	<i>Exposure Scenarios</i>	22
2.3.2	<i>Risk Characterization</i>	24
2.3.3	<i>Risk Management Thresholds as a Basis for Remedial Action Objectives</i>	29
3.0	PREVIOUS MITIGATION ACTIVITIES AND TECHNOLOGY STUDIES	31
3.1	VAPOR INTRUSION PREVENTION SYSTEMS	31
3.2	BACKYARD WELL ABANDONMENTS	31
3.3	TECHNOLOGY AND AQUIFER STUDIES	31
4.0	REMEDIAL ACTION OBJECTIVES AND CLEANUP GOALS	33
4.1	APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS	33
4.2	REMEDIAL ACTION OBJECTIVES	34
4.3	CLEANUP GOALS	35
4.4	AREAS AND VOLUME OF IMPACTED MEDIA	37
4.4.1	<i>Soil</i>	37
4.4.2	<i>Ground Water</i>	37
4.4.3	<i>Indoor Air</i>	38
5.0	IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES	39
5.1	GENERAL RESPONSE ACTIONS	39
5.2	SCREENING OF REMEDIAL TECHNOLOGY PROCESS OPTIONS	40
5.2.1	<i>Screening Criteria</i>	40
5.2.2	<i>Screening of Technology Process Options</i>	41
5.3	DESCRIPTION OF RETAINED TECHNOLOGIES	42
5.3.1	<i>Institutional Controls</i>	42
5.3.2	<i>Vapor Intrusion Prevention Systems</i>	42
5.3.3	<i>Private Well Removal</i>	42
5.3.4	<i>Monitored Natural Attenuation</i>	43
5.3.5	<i>Enhanced Anaerobic Bioremediation</i>	43
5.3.6	<i>In Situ Chemical Oxidation</i>	44
5.3.7	<i>Zero-Valent Iron Permeable Reactive Barrier</i>	45

5.3.8	<i>Ground Water Extraction, Treatment, and Disposal</i>	46
6.0	DEVELOPMENT OF REMEDIAL ALTERNATIVES	48
6.1	MEDIA AND AREAS CONSIDERED	49
6.1.1	<i>Soil</i>	49
6.1.2	<i>A-Zone Ground Water</i>	49
6.1.3	<i>B-Zone Ground Water</i>	50
6.1.4	<i>Residential Indoor Air</i>	50
6.2	REMEDICATION DURATION ESTIMATES	50
6.3	THREE COMPONENTS COMMON TO "ACTIVE REMEDIATION" ALTERNATIVES	50
6.3.1	<i>Soil Management Plan for Arsenic in Soil</i>	51
6.3.2	<i>Vapor Intrusion Prevention Systems</i>	52
6.3.3	<i>Private Well Removal</i>	52
6.4	DESCRIPTION OF REMEDIAL ALTERNATIVES	53
6.4.1	<i>Remedial Alternative 1</i>	53
6.4.2	<i>Remedial Alternative 2</i>	53
6.4.3	<i>Remedial Alternative 3</i>	54
6.4.4	<i>Remedial Alternative 4</i>	59
6.4.5	<i>Remedial Alternative 5</i>	60
6.4.6	<i>Remedial Alternative 6</i>	62
7.0	DETAILED COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES	65
7.1	DETAILED EVALUATION CRITERIA	66
7.1.1	<i>Federal Evaluation Criteria</i>	66
7.2	DETAILED EVALUATION OF REMEDIAL ALTERNATIVES	68
7.2.1	<i>Remedial Alternative 1 (No Action)</i>	68
7.2.2	<i>Remedial Alternative 2 (MNA and Common Components)</i>	69
7.2.3	<i>Remedial Alternative 3 (A-Zone Bioremediation, B-Zone Chemical Oxidation, and Common Components)</i>	71
7.2.4	<i>Remedial Alternative 4 (A-Zone PRB, B-Zone Chemical Oxidation, and Common Components)</i>	73
7.2.5	<i>Remedial Alternative 5 (A-Zone and B-Zone PRB and Common Components)</i>	75

7.2.6	<i>Remedial Alternative 6 (Ground Water Extraction, Treatment, and Disposal, and Common Components)</i>	77
7.3	COMPARATIVE ANALYSIS	79
7.3.1	<i>Overall Protection of Human Health and the Environment</i>	79
7.3.2	<i>Compliance with ARARs</i>	80
7.3.3	<i>Long-Term Effectiveness and Permanence</i>	80
7.3.4	<i>Reduction of Toxicity, Mobility, or Volume through Treatment</i>	81
7.3.5	<i>Short-Term Effectiveness</i>	82
7.3.6	<i>Implementability</i>	84
7.3.7	<i>Cost</i>	84
7.3.8	<i>State and Community Acceptance</i>	84
7.4	PREFERRED REMEDIAL ALTERNATIVE	84
8.0	IMPLEMENTATION PLAN	86
8.1	PRE-DESIGN INVESTIGATIONS	87
8.1.1	<i>Monitoring Well Installation and Baseline Sampling</i>	87
8.1.2	<i>Direct-Push Sampling</i>	88
8.1.3	<i>PRB Bench-Scale Testing</i>	88
8.1.4	<i>Chemical Oxidation Pilot Testing</i>	89
8.2	REMEDIAL DESIGN, DOCUMENTATION, AND PERMITTING	90
8.2.1	<i>Pre-Design Investigation Work Plan</i>	90
8.2.2	<i>Remedial Design</i>	90
8.2.3	<i>Soil Management Plan</i>	90
8.3	IMPLEMENTATION OF ALTERNATIVE COMPONENTS	91
8.3.1	<i>A-Zone Zero-Valent Iron PRB</i>	91
8.3.2	<i>B-Zone Chemical Oxidation</i>	92
8.3.3	<i>Vapor Intrusion Prevention Systems</i>	93
8.3.4	<i>Private Well Removal</i>	93
8.3.5	<i>Land Use Restrictions and Institutional Controls</i>	94
8.4	EFFECTIVENESS MONITORING	94
8.4.1	<i>Ground Water Monitoring</i>	94
8.4.2	<i>Indoor Air Monitoring</i>	95
8.5	IMPLEMENTATION SCHEDULE	96

LIST OF FIGURES

(Figures immediately follow text)

Figure 1-1 Parcel Location Map

Figure 1-2 Hookston Station Vicinity Map

Figure 1-3 Hookston Station Parcel and Adjacent Environmental Sites

Figure 2-1 Geological Cross Section

Figure 2-2 Ground Water Elevation Map, A-Zone – 23 January 2006

Figure 2-3 Ground Water Elevation Map, B-Zone – 23 January 2006

Figure 2-4 Ground Water Elevation Map, C-Zone – 23 January 2006

Figure 2-5 TCE Concentrations in Soil

Figure 2-6 Soil Arsenic Concentrations

Figure 2-7 PCE in Active Soil Vapor Samples, October 2003 – June 2006

Figure 2-8 TCE in Active Soil Vapor Samples, October 2003 – June 2006

Figure 2-9 cis-1,2-DCE in Active Soil Vapor Samples, October 2003 – June 2006

Figure 2-10 Vinyl Chloride in Active Soil Vapor Samples, October 2003 – June 2006

Figure 2-11 PCE Isoconcentration Map, A-Zone Ground Water – First Quarter 2006

Figure 2-12 TCE Isoconcentration Map, A-Zone Ground Water – First Quarter 2006

Figure 2-13 cis-1,2-DCE Isoconcentration Map, A-Zone Ground Water – First Quarter 2006

Figure 2-14 1,1-DCE Isoconcentration Map, A-Zone Ground Water – First Quarter 2006

- Figure 2-15 PCE Isoconcentration Map, B-Zone Ground Water – First Quarter 2006*
- Figure 2-16 TCE Isoconcentration Map, B-Zone Ground Water – First Quarter 2006*
- Figure 2-17 cis-1,2-DCE Isoconcentration Map, B-Zone Ground Water – First Quarter 2006*
- Figure 2-18 1,1-DCE Isoconcentration Map, B-Zone Ground Water – First Quarter 2006*
- Figure 2-19 Surface Water and Sediment Sample Locations*
- Figure 2-20 TCE in Residential Indoor Air (2004-2006)*
- Figure 2-21 PCE in Residential Indoor Air (2004-2006)*
- Figure 4-1 Residential Indoor Air Relative to Risk-Based Cleanup Goal*
- Figure 5-1 Conceptual View Direct-Push Injection System*
- Figure 5-2 Conceptual View Permeable Reactive Barrier Technology*
- Figure 5-3 Conceptual View Ground Water Extraction Treatment and Disposal*
- Figure 6-1 Remedial Alternative 1 – Conceptual Cross Section View*
- Figure 6-2 Remedial Alternative 2 – Conceptual Cross Section View*
- Figure 6-3 Remedial Alternative 2 – Monitored Natural Attenuation*
- Figure 6-4 Remedial Alternative 3 – Conceptual Cross Section View*
- Figure 6-5 Remedial Alternative 3 – Enhanced Anaerobic Bioremediation*
- Figure 6-6 Remedial Alternative 3 –A-Zone Detailed View – Hookston Station Parcel*
- Figure 6-7 Remedial Alternative 3 –A-Zone Detailed View – Downgradient Study Area*

- Figure 6-8 Remedial Alternative 3 -B-Zone Detailed View – Hookston Station Parcel*
- Figure 6-9 Remedial Alternative 4 – Conceptual Cross Section View*
- Figure 6-10 Remedial Alternative 4 – Zero-Valent Iron Permeable Reactive Barrier*
- Figure 6-11 Remedial Alternative 4 -Detailed View – Hookston Station Parcel*
- Figure 6-12 Remedial Alternative 5 – Conceptual Cross Section View*
- Figure 6-13 Remedial Alternative 5 – Zero-Valent Iron Permeable Reactive Barrier*
- Figure 6-14 Remedial Alternative 6 – Conceptual Cross Section View*
- Figure 6-15 Remedial Alternative 6 – Ground Water, Extraction, Treatment, and Disposal*

LIST OF TABLES

(Tables immediately following Figures)

<i>Table 2-1</i>	<i>Summary of Remedial Investigation Results</i>
<i>Table 2-2</i>	<i>Summary of Risk Characterization for the Hookston Station Parcel</i>
<i>Table 2-3</i>	<i>Summary of Risk Characterization for the Downgradient Study Area</i>
<i>Table 4-1</i>	<i>Chemical-Specific Applicable or Relevant and Appropriate Requirements</i>
<i>Table 4-2</i>	<i>Action-Specific Applicable or Relevant and Appropriate Requirements</i>
<i>Table 4-3</i>	<i>Location-Specific Applicable or Relevant and Appropriate Requirements</i>
<i>Table 4-4</i>	<i>Chemical-Specific Requirements to be Considered</i>
<i>Table 4-5</i>	<i>Risk-Based Cleanup Goals</i>
<i>Table 5-1</i>	<i>Soil Remedial Technologies and Process Options</i>
<i>Table 5-2</i>	<i>Ground Water Remedial Technologies and Process Options</i>
<i>Table 5-3</i>	<i>Summary of Screening – Retained Remedial Technologies</i>
<i>Table 6-1</i>	<i>Remedial Alternative Summary</i>
<i>Table 7-1</i>	<i>Selected Components of Remedial Alternatives</i>
<i>Table 7-2</i>	<i>Summary of Detailed Analysis – Remedial Alternative 1</i>
<i>Table 7-3</i>	<i>Summary of Detailed Analysis – Remedial Alternative 2</i>
<i>Table 7-4</i>	<i>Summary of Detailed Analysis – Remedial Alternative 3</i>
<i>Table 7-5</i>	<i>Summary of Detailed Analysis – Remedial Alternative 4</i>

Table 7-6 Summary of Detailed Analysis – Remedial Alternative 5

Table 7-7 Summary of Detailed Analysis – Remedial Alternative 6

Table 7-8 Summary of Comparative Analysis of Remedial Alternatives

Table 8-1 Preliminary Implementation Schedule

LIST OF APPENDICES

(Appendices immediately follow Tables)

<i>A</i>	<i>Additional Soil Arsenic Sampling</i>
<i>B</i>	<i>Soil Vapor Sampling</i>
<i>C</i>	<i>Chemical Oxidation Treatability Study</i>
<i>D</i>	<i>Fate and Transport Evaluation</i>
<i>E</i>	<i>Soil Vapor Extraction Pilot Test</i>
<i>F</i>	<i>Geotechnical Laboratory Report</i>
<i>G</i>	<i>Aquifer Testing</i>
<i>H</i>	<i>Risk-Based Cleanup Concentrations for Chemicals of Concern</i>
<i>I</i>	<i>Ground Water Modeling</i>
<i>J</i>	<i>Cost Estimates for Remedial Alternatives</i>

LIST OF ACRONYMS

<u>Acronym</u>	<u>Definition</u>
ARAR	Applicable or Relevant and Appropriate Requirements
bgs	Below ground surface
BRA	Baseline Risk Assessment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulation
CHHSL	California Human Health Screening Levels
COC	Contaminant of concern
CPT	Cone penetrometer testing
CTEH	Center for Toxicology and Environmental Health
CVOC	Chlorinated volatile organic compound
DCE	Dichloroethene
ERM	ERM-West, Inc.
EPA	Environmental Protection Agency
ESL	Environmental Screening Level
FS	Feasibility Study
GRA	General Response Action
IRM	Interim Remedial Measure
m ³ /day	Cubic meters of air per day
MCL	Maximum Contaminant Level

<u>Acronym</u>	<u>Definition</u>
mg/kg	Milligram per kilogram
MIP	Membrane interface probe
MNA	Monitored Natural Attenuation
MTBE	Methyl-tert-butyl ether
NCP	National Contingency Plan
NPV	Net present value
O&M	Operation and Maintenance
PCB	Polychlorinate biphenyl
PCE	Tetrachloroethene
pH	Acidity/alkalinity
PPE	Personal protective equipment
PRB	Permeable reactive barrier
RA	Risk Assessment
RAO	Remedial Action Objectives
RI	Remedial Investigation
RP	Responsible Parties
RWQCB	San Francisco Bay Regional Water Quality Control Board
SMP	Soil Management Plan
SVE	Soil Vapor Extraction
SVOC	Semivolatile organic compound
T&R	Treadwell & Rollo

<u>Acronym</u>	<u>Definition</u>
TBC	To be considered
TCE	Trichloroethene
TMV	Toxicity, mobility, and volume
TPH	Total petroleum hydrocarbon
USEPA	United States Environmental Protection Agency
VOC	Volatile organic compound
µg/kg	Microgram per kilogram
µg/L	Microgram per liter
µg/m ³	Microgram per cubic meter

EXECUTIVE SUMMARY

This Feasibility Study (FS) has been submitted to the Regional Water Quality Control Board San Francisco Bay Region (RWQCB) by ERM-West, Inc. (ERM) on behalf of the Hookston Station Responsible Parties (RPs) for the Hookston Station Parcel in Pleasant Hill, California. The Hookston Station RPs include Union Pacific Railroad, Daniel C. Helix, Mary Lou Helix, Elizabeth Young, John V. Hook, Steven Pucell, Nancy Ellicock, and the Contra Costa County Redevelopment Agency. This FS has been prepared to comply with the requirements of RWQCB Order Number R2-2003-0035 (16 April 2003) and amended Order Number R2-2004-0081 (15 September 2004). The primary environmental concern associated with the Hookston Station Parcel is volatile organic compounds (VOCs) in soil, soil vapor, and ground water. The goal of the FS is to develop a final remediation program that is protective of human health and the environment. This FS has been developed in compliance with the *National Oil and Hazardous Substance Pollution Contingency Plan* (Code of Federal Regulations 40, Part 300 et seq.) and *Guidance for Conducting Remedial Investigations and Feasibility Studies Under the Comprehensive Environmental Response, Compensation and Liability Act* (United States Environmental Protection Agency [USEPA] 1988).

The *Remedial Investigation Report* (ERM 2004) and *Baseline Risk Assessment* (CTEH 2006) have been submitted to and approved by the RWQCB. These documents provide the basis for the remedial action objectives, cleanup goals, and impacted areas/volume of media that are presented in this FS. A range of potentially applicable remedial approaches were screened according to the criteria of effectiveness, implementability, and cost. The screening process was used to develop six remedial alternatives for further consideration to identify a final remedy. These six alternatives were subjected to a detailed comparative analysis based on the following seven of the nine USEPA evaluation criteria:

- Protection of Human Health and the Environment;
- Compliance with Applicable or Relevant and Appropriate Requirements;

- Long-Term Effectiveness;
- Reduction in Toxicity, Mobility, and Volume;
- Short-Term Effectiveness;
- Implementability; and
- Cost.

Based on the comparative analysis, Remedial Alternative 4 was selected as the final remedy for the Hookston Station Parcel and downgradient study area. This alternative best meets the risk management goals in light of the seven evaluation criteria, and includes the following components:

- Installation of a permeable reaction barrier with zero valent iron in the A-Zone to remediate ground water.
- Implementation of in situ chemical oxidation in the B-Zone to remediate ground water.
- Implementation of vapor intrusion prevention systems to address migration of VOCs from ground water to indoor air in residences.
- Institutional controls for a single isolated area of arsenic in soil on the Hookston Station Parcel that will remain in place, involving implementation of a Soil Management Plan.
- Institutional controls for ground water prohibiting use until water quality goals are met.
- Institutional controls for ground water in the downgradient study area involving prohibiting use until water quality goals are met.

This FS also presents an Implementation Plan for the final remedy. This plan presents the process and schedule that would be followed to implement the remedial program. This plan includes the following primary elements:

- Pre-Design Investigations;
- Remedial Design;

- Pre-Implementation Documentation and Permitting;
- Contracting and Procurement;
- Implementation of Remedy; and
- Effectiveness Monitoring.

The Hookston Station RPs have developed a remedial strategy that addresses the chemicals originating at Hookston Station in a manner that is protective of human health and the environment. The remedial program selected in this FS is designed to address those chemicals. The residential area to the northeast of Hookston Station is also being impacted by chemicals originating from other source areas. The non-Hookston Station sources of those additional ground water contaminants must also be identified and remediated to assure attainment of the final remedial action objectives in the residential area.

1.0

INTRODUCTION

On behalf of the Hookston Station Responsible Parties (Hookston RPs), ERM-West, Inc. (ERM) has prepared this *Feasibility Study* (FS) for the approximately 8-acre property known as the Hookston Station property (hereinafter referred to as “Hookston Station Parcel”) and the mixed ground water plume located northeast of the Hookston Station Parcel (hereinafter referred to as the “downgradient study area”). The Hookston RPs include Union Pacific Railroad Company, Daniel C. Helix, Mary Lou Helix, Elizabeth Young, John V. Hook, Steven Pucell, Nancy Ellicock, and the Contra Costa County Redevelopment Agency. The Hookston Station Parcel is located at the intersection of Hookston and Bancroft Roads in Pleasant Hill, California (Figure 1-1). Chlorinated volatile organic compounds (CVOCs), including trichloroethene (TCE) and other CVOCs, have been detected in soil, soil vapor, ground water, and indoor air at and downgradient of the Hookston Station Parcel. The chemicals of concern that originate from the Hookston Station Parcel include TCE and associated degradation compounds. This document presents a remediation program to protect human health and the environment in accordance with Regional Water Quality Control Board (RWQCB) Order No. R2-2003-0035, dated 16 April 2003 (amended on 15 September 2004 as Order No. R2-2004-0081).

1.1

REPORT ORGANIZATION

This document is organized as follows:

- Section 1.0 states the purpose of this document and presents the Hookston Station Parcel background information;
- Section 2.0 presents a summary of the remedial investigation and the human health risk assessment conducted for Hookston Station Parcel and the downgradient study area;
- Section 3.0 describes previous remedial actions and technology studies that have been completed;

- Section 4.0 develops the Remedial Action Objectives (RAOs) for the FS, and discusses Applicable or Relevant and Appropriate Requirements (ARARs), cleanup goals, and impacted areas/media;
- Section 5.0 identifies and screens potentially applicable remedial technologies and response actions for the Hookston Station Parcel and downgradient study area;
- Section 6.0 describes the remedial alternatives developed for evaluation based on applicable screening criteria;
- Section 7.0 presents a detailed and comparative analysis of remedial alternatives using accepted evaluation criteria to select a final remedy for the Hookston Station Parcel and downgradient study area;
- Section 8.0 presents an implementation plan for the selected remedial alternative; and
- Section 9.0 presents references for the FS.

Tables, figures, and appendices referenced in this report are provided following the text. This report includes 10 appendices as follows:

- Appendix A – Additional Soil Arsenic Sampling;
- Appendix B – Soil Vapor Sampling;
- Appendix C – Chemical Oxidation Treatability Study;
- Appendix D – Fate and Transport Evaluation;
- Appendix E – Soil Vapor Extraction (SVE) Pilot Test;
- Appendix F – Geotechnical Laboratory Report;
- Appendix G – Aquifer Testing;
- Appendix H – Risk-Based Cleanup Concentrations for Chemicals of Concern;
- Appendix I – Ground Water Modeling; and

- Appendix J – Remedial Alternatives Cost Analyses.

1.2

PURPOSE OF REPORT

The objective of this FS is to develop a remediation program for the Hookston Station Parcel and downgradient study area that is protective of human health and the environment. The Remedial Investigation (RI) and FS process represents methodology that has been established by the United States Environmental Protection Agency (USEPA) for characterizing the nature and extent of risks posed by hazardous waste sites and for evaluating potential remedial options to address these risks. The objective of the process is to gather sufficient information to support an informed risk management decision regarding the most appropriate remedy for a site.

The FS serves as the mechanism for the development, screening, and detailed evaluation of alternative remedial actions. The FS utilizes the information developed during the RI and Baseline Risk Assessment (BRA) to:

- Develop specific RAOs and cleanup goals;
- Identify and screen applicable remedial technologies;
- Develop remedial alternatives using applicable technologies and management options;
- Conduct a comparative evaluation of remedial alternatives; and
- Recommend a specific remedial alternative to address the risks posed by site-related chemicals of concern.

This FS has been developed in compliance with USEPA guidance for preparation of FS documents (*Guidance for Conducting Remedial Investigations and Feasibility Studies Under the Comprehensive Environmental Response, Compensation and Liability Act [CERCLA, USEPA 1988b]* and the *National Oil and Hazardous Substance Pollution Contingency Plan [Title 40 of the Code of Federal Regulations [CFR], Part 300 et seq.]*).

1.3 BACKGROUND

This section summarizes background and historical information regarding the Hookston Station Parcel and the surrounding area.

1.3.1 *Hookston Station Parcel Location and Physical Description*

The Hookston Station Parcel property boundaries are shown on Figure 1-2. The area encompassed by the property boundaries shown on Figure 1-2 is referred to in this FS as the Hookston Station Parcel.

The Hookston Station Parcel is located near the intersection of Hookston Road and Bancroft Road in Contra Costa County, Pleasant Hill, California. Figure 1-1 illustrates the location of the Hookston Station Parcel.

The property boundaries form an elongated strip that runs north to south along a former railroad right-of-way and encompass an area of approximately 8 acres. The physical characteristics of the Hookston Station Parcel are shown on Figure 1-2. The Hookston Station Parcel includes the following four addresses:

- 199 Mayhew Way;
- 222 Hookston Road;
- 228 Hookston Road; and
- 230 Hookston Road.

The eastern half of the Hookston Station Parcel is mostly vacant, with only one structure associated with 230 Hookston Road. Gravel and overgrown vegetation, with limited amounts of asphalt pavement, cover the ground surface of this portion of the Hookston Station Parcel.

The structures and operations associated with 199 Mayhew Way and 222 and 228 Hookston Road are situated on the western portion of the Hookston Station Parcel. The areas surrounding these structures are utilized for parking and driveways and are mostly covered with asphalt pavement with few gravel areas.

Pedestrian access to the Hookston Station Parcel is mostly limited to narrow alleyways that lead from Hookston Road to the north and

Mayhew Way to the south due to chain-link fencing and existing structures. The City of Concord recently installed a pedestrian/bike path that extends the Iron Horse Trail along the eastern property boundary, and now diverts this local foot traffic away from the industrial and commercial operations at the Hookston Station Parcel.

1.3.2 *Historical and Current Uses of the Hookston Station Parcel*

The Hookston Station Parcel was operated by Southern Pacific Transportation Company as a portion of the San Ramon Branch rail line from approximately 1891 to 1965. During that time, the Hookston Station Parcel included a freight-loading platform with railroad sidings and was used as a station for loading fruit and lumber.

Between approximately 1965 and 1983, the land was developed into a mixed light-industrial business complex, and was occupied by auto-related businesses, lumber yards, furniture manufacturing, metal working shops, and masonry works. Additional information related to historical business practices and chemical use at the Hookston Station Parcel is described in the *Site History Data Summary* (ERM 2003a).

The property ownership was transferred from the Southern Pacific Transportation Company to Daniel C. Helix, Mary Lou Helix, Elizabeth Young, John V. Hook, Steven Pucell, and Nancy Ellicock, in 1983. The Contra Costa County Redevelopment Agency subsequently acquired the eastern portion of the Hookston Station Parcel from these owners in 1989. The western portion of the Hookston Station Parcel has been sublet to various auto-related businesses including repair and body shops, as well as warehouse space, a lumber yard, an upholstery shop, a masonry shop, and a feed store. The eastern portion of the Hookston Station Parcel was previously occupied by lumber yards, recycling facilities, auto-related businesses, machining repair shops, and a roofing company.

The Hookston Station Parcel is currently used exclusively for industrial and commercial activities. A feed and pet supply store occupies the majority of the northeastern portion of the Hookston Station Parcel, including the structures at 222 and 228 Hookston Road. The structure at 199 Mayhew Way is divided into several smaller suites, which are occupied by two automobile maintenance and body shops, a window and cabinet (woodworking) shop, a wood milling facility, and storage units. A

concrete batch plant is present on a portion of the eastern half of the Hookston Station Parcel at 230 Hookston Road. The vacant portions on the eastern half of the Hookston Station Parcel were most recently operated as a lumberyard and a recycling facility.

Future use of the Hookston Station Parcel is likely to remain industrial/commercial, similar to current land use. No plans are known to exist for redevelopment of the Hookston Station Parcel. Given this land use, it is not expected that new water supplies (new supply wells) will be developed at the Hookston Station Parcel.

1.3.3 *Surrounding Land Use*

The properties surrounding the Hookston Station Parcel include residential areas and mixed office/commercial/light industrial enterprises (Figure 1-2). Private residences, consisting of single-family homes, town homes, and apartment buildings, are located northeast, east, and south of the Hookston Station Parcel. The Hookston Station Parcel is bordered to the west by mixed-use operations, including business offices, commercial spaces, and some light industry. A bulk fuel storage and distribution facility (Pitcock Petroleum/Chevron Products) is also located immediately west of the Hookston Station Parcel near the northwestern property boundary. A self-storage business and small community park are situated north of the Hookston Station Parcel.

1.3.4 *Beneficial Uses of Ground Water and Surface Water*

The current and future potential beneficial uses of the ground water and surface water are those identified in the *Water Quality Control Plan for the San Francisco Bay Basin* (Basin Plan) (RWQCB 1995) for the Suisun Basin and Ygnacio Valley Ground Water Basin. The current and future potential beneficial uses have been considered in the development of the RAOs for the Hookston Station Parcel and downgradient study area, as described in Section 4.

1.3.4.1 *Existing Beneficial Uses*

The Basin Plan identifies the existing beneficial use of ground water at the Hookston Station Parcel and surrounding areas as domestic water supply. Well surveys conducted by ERM (Section 2.1.1) identified several private

wells on residential properties downgradient of the Hookston Station Parcel. The survey results indicated that the wells were limited to use for irrigation purposes, if used at all, and none of the wells were used for drinking water. Additional existing beneficial uses of ground water at and near the Hookston Station Parcel have not been identified.

The existing beneficial uses of surface water near the Hookston Station Parcel include warm and cold fresh water habitats, fish migration and spawning, and wild life habitat.

1.3.4.2 *Potential Beneficial Uses*

As outlined in the Basin Plan, potential beneficial uses of ground water at and near the Hookston Station Parcel include the following:

- Municipal and domestic water supply;
- Industrial process water supply;
- Industrial service water supply; and
- Agricultural water supply.

In addition to the existing beneficial uses, the Basin Plan identifies the following potential beneficial uses for Walnut Creek, the surface water body closest to the Hookston Station Parcel (additional information regarding surface water is provided in Section 2.1):

- Water contact recreation; and
- Non-contact water recreation.

1.3.5 *Hookston Station Parcel Regulatory Background*

The first environmental investigation at the Hookston Station Parcel was completed on behalf of the Contra Costa County Public Works Department in 1990. Several subsequent phases of soil and ground water investigation were completed between 1990 and 1996. These investigations were completed under the direction of Contra Costa County Hazardous Materials Division, a division of the Contra Costa

County Health Services Department. Copies of those investigation reports were also submitted to the RWQCB.

The RWQCB has overseen investigation and remedial activities conducted at the Hookston Station Parcel and downgradient study area since 2000. On 16 April 2003, the RWQCB issued an Initial Site Cleanup Requirement (Order No. R2-2003-0035) for the Hookston Station Parcel. That Order required completion of the following 10 tasks:

- Task 1 – Source Area Investigation Work Plan (completed);
- Task 2 – Community Relations Plan (completed);
- Task 3 – Risk Assessment Work Plan (completed);
- Task 4 – Area Well Survey (completed);
- Task 5 – RI Work Plan (completed);
- Task 6 – Source Area Investigation/Interim Remedial Measures (IRM) Work Plan (completed);
- Task 7 – Implementation of Source Area IRM (completed [none required]);
- Task 8 – Risk Assessment (completed);
- Task 9 – RI (completed); and
- Task 10 – Feasibility Study (this document).

The RWQCB amended the 16 April 2003 Order on 15 September 2004 (Order No. R2-2004-0081). The amended Order required the following tasks be completed for the Hookston Station Parcel and downgradient study area:

- Task 8a – Indoor Air Sampling Work Plan (completed);
- Task 8b – Baseline Human Health Risk Assessment (completed); and
- Task 8c – Indoor Air Sampling Report (completed).

1.3.6

Adjacent Environmental Sites

In addition to TCE, additional volatile organic compounds (VOCs), including tetrachloroethene (PCE) and methyl tert butyl ether (MTBE) have been detected in ground water at and near the Hookston Station Parcel. The RWQCB has concluded that the PCE and MTBE ground water impacts originate from other nearby properties, not the Hookston Station Parcel (RWQCB 2006b). The sources of these chemicals are discussed below and depicted on Figure 1-3.

- The Pitcock Petroleum site (220 Hookston Road) is characterized by petroleum hydrocarbon impacts to ground water, including MTBE, benzene, and total petroleum hydrocarbons (TPH) at concentrations exceeding the drinking water Maximum Contaminant Levels (MCLs). These ground water impacts flow in a northeasterly direction and have migrated below the Hookston Station Parcel and additional properties located northeast (downgradient) of 220 Hookston Road. The downgradient extent of these ground water impacts has not yet been determined. The RWQCB is requiring the owners of the Pitcock Petroleum site to conduct additional investigation activities of the hydrocarbon impacts (RWQCB 2006c).
- TCE and PCE (a VOC that degrades to TCE and other chlorinated VOCs) have been identified in ground water west of Vincent Road. This PCE/TCE plume is referred to herein after as the "Vincent Road PCE/TCE plume" or "Vincent Road PCE/TCE source area", and is situated upgradient of the Hookston Station Parcel. Ground water within the Vincent Road PCE/TCE ground water plume flows in a northeasterly direction below the northern portion of the Hookston Station Parcel and contains concentrations of PCE and TCE at concentrations exceeding the MCLs. As stated previously, PCE is not a chemical that originates from the Hookston Station Parcel. The RWQCB has required the property owners of 3301-3341 Vincent Road, 3343-3355 Vincent Road, and 81 Mayhew Way to perform soil and ground water investigations in an attempt to identify the source area(s) and responsible party(ies) for these impacts.

The Vincent Road PCE/TCE ground water plume and the Pitcock Petroleum ground water plume mix in the northwestern portion of the Hookston Station Parcel. Chemicals originating from the Hookston

Station Parcel mix with these two other VOC plumes northeast of the Hookston Station Parcel. This mixed plume flows in a northeasterly direction beyond the Hookston Station Parcel and below the neighborhood located northeast of the Hookston Station Parcel. This mixed plume area outside of the Hookston Station Parcel is referred to hereinafter as the “downgradient study area.”

The Hookston RPs are currently investigating specific locations along Bancroft Road to determine if they may be separate additional source(s) of VOCs contributing to the mixed ground water plume in the downgradient study area.

SUMMARY OF REMEDIAL INVESTIGATION AND HEALTH RISK ASSESSMENT

In accordance with Orders No. R2-2003-0035 and R2-2004-0081, the Hookston RPs have completed the RI and BRA. The results of these activities were presented in the following documents:

- *Remedial Investigation Report* (ERM 2004) (RI Report), conditionally approved by the RWQCB on 19 November 2004; and
- *BRA* (CTEH 2006), approved by the RWQCB on 10 March 2006.

Together, these reports define the constituents of concern; the extent of impacts in soil, soil vapor, ground water, air, surface water, and sediment; and the potential human health risks associated with current conditions. This section of the FS summarizes the portions of the RI and BRA that are relevant to the calculation of clean up goals, technology screening, and selection of an appropriate remedial alternative.

REMEDIAL INVESTIGATION SUMMARY

RI activities were conducted to evaluate the nature and extent of TCE impacts originating from the Hookston Station Parcel. As part of the RI, the Hookston RPs also conducted limited investigation activities of ground water impacts that originate from the Vincent Road PCE/TCE source area (Section 1.3.6). CVOCs were detected in soil, soil vapor, ground water, and indoor air at the Hookston Station Parcel and in soil vapor, ground water, and indoor air within the downgradient study area. CVOCs were also detected in ground water and soil vapor near the Vincent Road PCE/TCE source area.

This summary of the RI results includes the following:

- A summary of investigation activities;
- A description of the geologic and hydrogeologic setting;
- Identification of chemicals found in soil and description of their nature and extent;
- Identification of chemicals found in soil vapor and description of their nature and extent;

- Identification of chemicals found in ground water and description of their nature and extent;
- Identification of chemicals found in indoor air and description of their nature and extent; and
- Identification of chemicals found in surface water and sediment and description of their nature and extent.

2.1.1 *Field Investigation Activities*

Several preliminary phases of investigations were conducted between 1989 and 1996 on behalf of various parties by different consultants. Those investigation activities included soil, soil vapor, and ground water investigations. For additional information, the reader is referred to the RI Report.

On behalf of the Hookston RPs, ERM conducted the RI in a phased approach between October 2001 and April 2004. Phase I of the RI included:

- Collection and analysis of soil samples and passive soil vapor samples;
- Collection and analysis of sediment and surface water samples from Walnut Creek;
- Collection and analysis of ground water samples from monitoring wells located on the Hookston Station Parcel and in the downgradient study area;
- Water level measurements from monitoring wells;
- Advancement of multilevel cone penetrometer testing borings;
- Surface vapor flux sampling; and
- Water well survey of existing well records on file with the State of California Department of Water Resources.

Phase II of the RI included:

- Source area soil and a regional ground water investigation that included the collection of additional soil and ground water samples from the Hookston Station Parcel;
- Active soil vapor investigation;

- Private well survey;
- Installation and sampling of additional monitoring wells on the Hookston Station Parcel, in the downgradient study area, and in the Vincent Road PCE/TCE ground water plume; and
- Collection of indoor air quality samples from structures located on the Hookston Station Parcel and in the downgradient study area.

For additional details, the reader is referred to the *Remedial Investigation Progress Report* (ERM 2002a), the *Source Area Investigation and Interim Remedial Measures Analysis Report* (ERM 2003b), and the RI Report previously referenced.

On-going activities that have continued include:

- Routine quarterly ground water quality monitoring since March 2001; and
- Routine quarterly soil vapor monitoring since April 2005.

The results of those monitoring events have been documented in quarterly reports prepared by ERM and submitted to the RWQCB.

2.1.2 *Geology and Hydrogeology*

The following sub-sections summarize the geologic, surface water, and ground water conditions of the Hookston Station Parcel and downgradient study area based on data collected during the RI and previous investigations.

2.1.2.1 *Geologic Setting*

The Hookston Station Parcel and surrounding area are underlain by unconsolidated deposits that extend to at least 100 feet below ground surface (bgs), as shown on Figure 2-1 and summarized below:

- Fine-grained clays and silts are present from the ground surface (or immediately below the ground surface cover materials) to depths typically ranging from 30 to 40 feet bgs. This zone has been defined by ERM as the “A-Zone”, and contains discontinuous lenses of sands, silty sands, and gravelly sands that are interbedded in the fine-grained deposits. These coarser grained lenses range in thickness from a few inches to approximately 11 feet, but are more commonly only a few feet in thickness.

- Beneath the A-Zone, a relatively continuous sand unit that is interbedded with silt and clay lenses is present between the approximate depths of 30 and 70 feet bgs. This zone has been defined by ERM as the “B-Zone”. The sands of the B-Zone are generally 5 to 10 feet thick and range from well-sorted sands, clayey sands, to gravelly sands; a few gravel zones are also encountered in this unit. The silt and clay lenses within the B-Zone are up to 10 feet thick but are generally less than a few feet thick.
- A clay unit that is 10 to 40 feet thick is present beneath the B-Zone.
- A deeper sand unit, defined by ERM as the “C-Zone”, is present beneath the clay unit and is initially encountered at depths ranging from 65 to 97 feet bgs. The C-Zone is also a continuous sand unit that is interbedded with silt and clay lenses. The C-Zone extends to approximately 100 feet bgs; the deposits deeper than 100 feet bgs have not been characterized.

2.1.2.2 *Surface Water Hydrology*

The Hookston Station Parcel and surrounding area are located within the Suisun Basin watershed of the San Francisco Bay Basin, as defined in the Basin Plan (RWQCB 1995). The nearest surface water body is Walnut Creek. The creek is located approximately 1,300 feet east/northeast (downgradient) of the Hookston Station Parcel and flows in a northerly direction for several miles before emptying into the Suisun Bay. The creek has been modified by the Contra Costa County Flood Control District and is currently part of an engineered storm water drainage network. The creek is unlined in the vicinity of the Hookston Station Parcel and is secured from public access by permanent fencing.

2.1.2.3 *Ground Water*

The Hookston Station Parcel and surrounding area are located within the Ygnacio Valley ground water basin, as outlined in the Basin Plan (RWQCB 1995). Ground water in the A-, B, and C-Zones flows in northeasterly to northerly directions. Ground water potentiometric surface maps for each water-bearing zone (based on the First Quarter 2006 monitoring event) are provided as Figures 2-2 through 2-4. The potentiometric ground water levels in each of these zones have historically ranged from approximately 12 to 23 feet bgs in the A-Zone, 13 to 24 feet bgs in the B-Zone, and 16 to 21 feet bgs in the C-Zone. The overall hydraulic gradients in the three zones have typically ranged from 0.001 to 0.004 foot per foot (ft/ft) across the entire monitored area. Based

on ground water level measurements and stratigraphy, the three water-bearing zones are confined to semi-confined.

2.1.3 *Chemical Occurrence in Soil*

Soil samples were collected at the Hookston Station Parcel for laboratory analysis of VOCs, TPH, semi-volatile organic compounds (SVOCs), polychlorinated biphenyls (PCBs), and metals. Soil analytical results were compared in the RI Report to the RWQCB's Environmental Screening Levels (ESLs) for soil where ground water is a current or potential drinking water source, as defined in *Screening For Environmental Concerns At Sites With Contaminated Soil and Groundwater, Volume 1: Summary Tier I Lookup Tables* (RWQCB 2003). Table 2-1 summarizes the soil chemical occurrence with respect to current ESLs (RWQCB 2005). Detailed information regarding soil sampling locations, summary data tables, and laboratory analytical reports are presented in the RI Report.

A total of 273 soil samples collected from 86 locations were analyzed for VOCs. The VOC concentrations in soil throughout the Hookston Station Parcel are generally low, with only a few sample concentrations exceeding the ESLs. TCE was the most frequently detected VOC in soil, but only seven of the 273 soil samples reported TCE concentrations greater than the TCE soil ESL (460 micrograms per kilogram [$\mu\text{g}/\text{kg}$]). The highest concentrations (up to 2,580 $\mu\text{g}/\text{kg}$) were detected in samples collected from 2 to 5 feet bgs from underneath or immediately adjacent to the 199 Mayhew Way structure. The TCE soil concentrations decrease rapidly with depth, with only a few samples reporting elevated TCE concentrations just above the static water level. Figure 2-5 illustrates the distribution of TCE in soil.

Nineteen surface soil samples were collected for metals analysis at the Hookston Station Parcel during the RI and previous investigations. Most of the samples contained metals concentrations and distributions that are consistent with background metals concentrations in California soils. Soil samples from two locations (B-69 and B-84) contained arsenic concentrations that appeared to be higher than background.

In May 2006, additional soil sampling was completed B-69 and B-84. Soil sampling was also conducted in June 2006 at one location (S-09) where arsenic was not previously detected but an elevated reporting limit (500 milligrams per kilogram [mg/kg]) was utilized in the analysis. The results of those studies indicated that arsenic concentrations were not elevated in surface soils at B-69, B-84 or S-09, but did indicate elevated arsenic concentrations in subsurface soils near B-69. The results of those sampling activities, along with a discussion on background concentrations

of arsenic in soils, are provided in Appendix A. Sampling locations and results are illustrated on Figure 2-6.

2.1.4 *Chemical Occurrence in Soil Vapor*

Soil vapor samples (also known as “soil gas” samples) have been collected using the following three methods during the RI, previous investigations by other consultants, quarterly monitoring events, and during recent (June 2006) sampling activities:

- *Passive soil vapor sampling*, which uses small adsorbent traps that are installed at a depth of approximately 3 feet bgs and remain in the subsurface for approximately 2 weeks;
- *Active soil vapor sampling from temporary direct-push sampling equipment* (for one-time sampling events). Active soil vapor samples are collected over a relatively short period of time, typically less than 1 hour per sample collected; and
- *Active soil vapor sampling through fixed soil vapor probes* (for long-term monitoring of particular portions of the study area). Active soil vapor samples are collected over a relatively short period of time, typically less than 1 hour per sample collected.

Passive soil vapor surveys were conducted during the RI and previous investigations by other consultants. These surveys focused on locations within the Hookston Station Parcel and locations along Vincent Road. Elevated concentrations of TCE in soil vapor were found beneath the 199 Mayhew Way structure and other areas of the Hookston Station Parcel toward the northeastern property boundary. Elevated concentrations of PCE were found in soil vapor along Vincent Road. These PCE impacts in the downgradient study area, which are not related to a release at the Hookston Station Parcel, prompted the RWQCB to request investigation activities at properties upgradient of the Hookston Station Parcel, as discussed in Section 1.3.6. Sampling locations, results, and laboratory reports were presented in the RI Report.

The active soil vapor survey conducted during Phase II of the RI focused on evaluating the VOC concentrations in soil vapor at locations where the greatest VOC concentrations were reported in ground water at the Hookston Station Parcel and in the downgradient study area. This work was completed as part of an area-wide vapor intrusion study. Results were compared in the RI Report to the soil vapor ESLs for Residential and Commercial/Industrial land use scenarios (RWQCB 2003) for locations in the downgradient study area and at the Hookston Station Parcel,

respectively. Concentrations of TCE in soil vapor greater than the ESLs were detected at one location at the Hookston Station Parcel and three locations in the downgradient study area. The results of this study led to the collection and analysis of indoor air samples as described in Section 2.1.7.

Permanent soil vapor monitoring probes were installed in April 2005 at 10 locations in the downgradient study area and are sampled on a quarterly basis. The probes are installed at six locations overlying the core of the mixed A-Zone ground water plume and at four locations within underground utility corridors located outside the footprint of the mixed A-Zone ground water plume.

Additional active soil vapor sampling was conducted in June 2006 at three locations in the downgradient study area. A description of those sampling activities and the laboratory analytical report is included in Appendix B.

TCE and PCE are the most frequently detected VOCs in soil vapor (based on data collected through June 2006) overlying the core of the mixed A-Zone ground water plume in the downgradient study area. PCE has also been detected in soil vapor at some of the locations within the utility corridors. The distribution of PCE, TCE, cis-1,2-dichloroethene (DCE), and vinyl chloride in soil vapor is illustrated on Figures 2-7 and 2-10, respectively. The results are compared with the current soil vapor ESLs (RWQCB 2005) and California Human Health Screening Levels (CHHSLs) (California Environmental Protection Agency [EPA] 2005) for residential land use scenarios in Table 2-1. TCE, cis-1,2-DCE, and vinyl chloride have been detected at concentrations greater than their respective ESLs or CHHSLs at one or more locations. Chemicals not originating from the Hookston Station Parcel (specifically PCE and benzene) have also been detected in soil vapor in the downgradient study area at concentrations above the ESLs or CHHSLs.

2.1.5 *Chemical Occurrence in Ground Water*

Ground water samples were collected during the RI and previous investigations from permanent monitoring wells, soil borings, and direct-push locations and analyzed for VOCs, SVOCs, dissolved metals, and/or petroleum hydrocarbons. Ground water samples are also collected from 44 permanent monitoring wells on a routine, quarterly basis for VOC analyses. Ground water sampling locations, summary data tables, and laboratory analytical reports are included in the RI Report and quarterly monitoring reports. Table 2-1 summarizes the ground water chemical occurrence with respect to current ESLs (RWQCB 2005) and MCLs.

Petroleum hydrocarbons are typically found in wells MW-4 and MW-22A, near the northwestern corner of the Hookston Station Parcel. Chemical impacts in this area are attributable to sources other than the Hookston Station Parcel, most notably the Pitcock Petroleum site.

Ground water samples were analyzed for dissolved metals during the RI. Detections of nine metals exceeded the MCLs. These detections were reported in various monitoring wells, located within and outside the mixed VOC ground water plume footprint (described further below). Based on the concentrations and distribution, these metals detections are attributed to naturally occurring levels of metals in ground water rather than man-made sources.

TCE and degradation products cis-1,2-DCE and 1,1-DCE are the most widespread compounds in A- and B-Zone ground water and are the primary chemicals of concern for the Hookston Station Parcel. Elevated concentrations of PCE have also been detected in A- and B-Zone ground water in the northern portion of the Hookston Station Parcel and along Vincent Road. PCE degrades to TCE, which degrades to less chlorinated compounds such as cis-1,2-DCE. These compounds have been detected at concentrations up to 7,200 micrograms per liter ($\mu\text{g/L}$) PCE, 22,000 $\mu\text{g/L}$ TCE, 5,800 $\mu\text{g/L}$ cis-1,2-DCE, and 1,300 $\mu\text{g/L}$ 1,1-DCE. The distributions of PCE, TCE, cis-1,2-DCE, and 1,1-DCE in A- and B-Zone ground water (based on First Quarter 2006 data) is illustrated on Figures 2-11 through 2-18. As stated in Section 1.3.6, PCE does not originate from the Hookston Station Parcel.

Few VOC detections have been reported in C-Zone ground water, and none have been detected during the four most recent quarterly monitoring events. Therefore, remediation of C-Zone ground water is not addressed in this FS.

2.1.6 *Chemical Occurrence in Surface Water and Sediment*

Surface water and sediment samples were collected from un-lined portions of Walnut Creek at locations up- and down-stream from the Hookston Station Parcel (Figure 2-19). The samples were analyzed for VOCs and the results were compared in the RI Report to the RWQCB's ESLs for freshwater surface water, Chronic and Acute Freshwater Aquatic Habitat Goals, and Surface Water Quality Standards for Bioaccumulation and Human Consumption of Aquatic Organisms (RWQCB 2003). Table 2-1 summarizes the surface water and sediment chemical occurrence with respect to current ESLs (RWQCB 2005). Sample locations, data summary tables, and laboratory analytical reports are included in the RI Report.

VOCs detected in surface water samples include PCE, TCE, cis-1,2-DCE, toluene, and MTBE. The final surface water ESLs, habitat goals, and surface water quality standards were not exceeded, with one exception. MTBE was detected in one surface water sample at a concentration of 8.3 µg/L, which exceeds the final surface water ESL of 5 µg/L MTBE. As stated in Section 1.3.6, MTBE does not originate from the Hookston Station Parcel.

No VOCs were detected in the sediment samples.

2.1.7 *Chemical Occurrence in Indoor Air*

As part of the RI and risk assessment activities, indoor air samples were collected from locations at the Hookston Station Parcel and in the downgradient study area during the following events:

- Indoor air samples were collected at the Hookston Station Parcel from five locations within the structure at 199 Mayhew Way during December 2003. Samples were analyzed for TCE, cis-1,2-DCE, and 1,1-DCE;
- Indoor air and crawl space air samples were collected from 18 private residences in the downgradient study area between January and September 2004. Samples were analyzed for TCE, cis-1,2-DCE, and 1,1-DCE. PCE results were subsequently quantified for selected samples using laboratory chromatograms; and
- Indoor air and crawl space air samples were collected from 42 private residences in the downgradient study area between August 2005 and January 2006. This sampling program was implemented during Summer 2005 in order to collect additional dry season indoor air quality data for homes sampled during 2004 and to collect samples from homes within the study area that did not participate in 2004. Samples were analyzed for 17 VOCs, including PCE, TCE, cis-1,2-DCE, and 1,1-DCE.

The results of these sampling events were included in the RI Report and the *Indoor Air Sampling Report* (ERM 2006). The indoor air sampling locations, summary data tables, and laboratory analytical results were provided in those documents.

Indoor air samples collected from within the 199 Mayhew Way structure reported concentrations up to 4.9 micrograms per cubic meter (µg/m³) TCE and 1.4 µg/m³ cis-1,2-DCE. Detectable levels of 1,1-DCE were not reported. The TCE concentrations reported in two samples exceeded the

Commercial/Industrial Use Indoor Air ESL ($2.0 \mu\text{g}/\text{m}^3$); the cis-1,2-DCE ESL was not exceeded.

Results of the 2004 and 2005/2006 residential indoor air sampling events were compared to the Residential Use indoor air ESLs (RWQCB 2005) and CHHSLs (California EPA 2005) (Table 2-1). The following is a summary of noteworthy results from the indoor air sampling events, listed in order of frequency of detection:

- **Benzene:** Indoor air samples collected from all 42 residences during the 2005-2006 event contained concentrations of benzene that exceed the CHHSL of $0.084 \mu\text{g}/\text{m}^3$. All crawl space and ambient air samples collected during the 2005-2006 event also reported benzene concentrations above $0.084 \mu\text{g}/\text{m}^3$. Benzene is not a chemical of concern associated with the Hookston Station Parcel.
- **PCE:** Indoor air samples from 43 private residences were analyzed for PCE during the 2004 and 2005/2006 events. Indoor air at 15 of these homes contained concentrations of PCE exceeding the CHHSL of $0.412 \mu\text{g}/\text{m}^3$. These residences are located throughout the downgradient study area. PCE is not a chemical of concern that originates from the Hookston Station Parcel. The residential indoor air PCE results are summarized on Figure 2-21.
- **TCE:** Indoor air samples for TCE analyses were collected from 47 private residences during the 2004 and 2005/2006 events. Indoor air at nine of the private residences contained concentrations of TCE in indoor air that exceed the CHHSL ($1.22 \mu\text{g}/\text{m}^3$ TCE) during the 2004 and/or 2005-2006 events. These residences are generally located within the footprint of the A-Zone mixed ground water plume in the downgradient study area where ground water TCE concentrations greater than approximately $500 \mu\text{g}/\text{L}$. The residential indoor air TCE results are summarized on Figure 2-20.
- **Vinyl chloride:** Indoor air samples for vinyl chloride analyses were collected from 42 homes during the 2005/2006 event. One home (1002 Hampton Drive) contained concentrations of vinyl chloride in indoor air exceeding the CHHSL of $0.0311 \mu\text{g}/\text{m}^3$. The source of this detection is not clear, as vinyl chloride was not detected in the crawl space air or in the ground water monitoring well adjacent to this home. Vinyl chloride was not detected in any other homes.
- **Additional VOCs:** Eight indoor air samples collected from 42 homes reported concentrations of 1,2-dichloroethane that exceed the CHHSL of $0.116 \mu\text{g}/\text{m}^3$. Additionally, 1,1,1-trichloroethane, 1,1-DCE, and

aromatic hydrocarbons (toluene, ethylbenzene, xylenes) were detected within the indoor air at several homes at low concentrations relative to their respective CHHSLs. None of these VOCs (except 1,1-DCE) are chemicals associated with the Hookston Station Parcel.

2.2

REGIONAL GROUND WATER QUALITY

The ground water quality of the area that encompasses the Hookston Station Parcel has been impacted by multiple sources of chemicals of concern, as follows.

- Hookston Station Parcel – TCE source area;
- Pitcock Petroleum – Petroleum hydrocarbon source area, including TPH, benzene, and MTBE; and
- Vincent Road Area – PCE/TCE source area.

Figure 1-3 illustrates the locations of these known source areas.

The Hookston Station Parcel TCE ground water plume originates in the southwestern portion of the Hookston Station Parcel and flows in a northeasterly direction. The Vincent Road Area PCE/TCE plume originates west of Vincent Road and flows in a northeasterly direction across the northern portion of the Hookston Station Parcel. Based on ground water chemistry and ground water flow data collected by the Hookston RPs, the CVOCs detected in monitoring wells MW-1, MW-4, MW-7, and MW-22A/MW-22B, which are located in the northwestern portion of the Hookston Station Parcel (Figures 2-11 to 2-18), are not associated with the Hookston Station Parcel TCE plume. These CVOC impacts, which include PCE and associated degradation products TCE and cis-1,2-DCE, are attributable to the upgradient Vincent Road PCE/TCE ground water plume. The Hookston Station Parcel and Vincent Road Area plumes mix in the northeastern portion of the Hookston Station Parcel and flow beneath the residential neighborhood located northeast of the Hookston Station Parcel. The RWQCB is currently working to identify the responsible party(ies) for the Vincent Road Area PCE/TCE plume.

Petroleum-related ground water impacts originating from the Pitcock Petroleum property flow in a northeasterly direction across the northern portion of the Hookston Station Parcel. Based on the ground water chemistry and flow data collected by the Hookston RPs, the petroleum hydrocarbon impacts detected in wells MW-1, MW-4, and MW-22A/B are

attributed to the Pitcock Petroleum site. These ground water impacts mix with the Vincent Road PCE/TCE plume in the northwestern portion of the Hookston Station Parcel. The downgradient extent of the Pitcock Petroleum ground water plume is currently being investigated by the responsible party.

The mixed plume that flows in a northeasterly direction beyond the Hookston Station Parcel and below the neighborhood located northeast of the Hookston Station Parcel comprises the downgradient study area.

The non-Hookston Station Parcel sources of these additional ground water contaminants must be identified and remediated to assure attainment of the final remedial action objectives in the residential area.

2.3 ***RISK ASSESSMENT SUMMARY***

The risk assessment process was initiated with the completion of the *Preliminary Risk Assessment* (ERM 2002b) in October 2002. In April 2004, the *Risk Assessment* (RA) (CTEH 2004) was completed. The RA extended the scope of the Preliminary Risk Assessment and incorporated RWQCB policy changes that occurred in 2003. These two initial documents summarized screening-level evaluations for potential risks associated with the Hookston Station Parcel. Following completion of the RA, the RWQCB requested completion of a more comprehensive BRA. The purpose of the BRA was to determine the need for cleanup and provide a baseline to compare remedial alternatives.

In February 2006, the BRA (CTEH 2006) was prepared and submitted to the RWQCB. The BRA estimates theoretical non-cancer and lifetime cancer risks for human exposure to chemicals of potential concern in each environmental medium. The BRA presented estimates of exposure to individuals at the Hookston Station Parcel and in the downgradient study area. The BRA was approved by the RWQCB on 10 March 2006 (RWQCB 2006a). Tables 2-2 and 2-3 present the exposure pathways and scenarios for the Hookston Station Parcel and downgradient study area, respectively, that were evaluated and the theoretical risk levels calculated for each complete exposure scenario. This summary reviews the exposure scenarios and risk characterization presented in the BRA.

2.3.1 ***Exposure Scenarios***

The BRA evaluated potentially exposed individuals at the Hookston Station Parcel and in the downgradient study area and possible exposure pathways (Tables 2-2 and 2-3). The following exposure pathways at the

Hookston Station Parcel were identified as complete and evaluated for potential risk characterization:

- Indoor (i.e., commercial/industrial) Workers
 - Inhalation of volatile chemicals in indoor air – VOCs may be released from subsurface soil or ground water into soil vapor, which can migrate to the surface and into a building;
 - Inadvertent ingestion of chemicals in soil – Workers contact surface soil directly as a component of their normal workday and potentially ingest soil;
 - Skin contact with chemicals in soil – Workers contact surface soil directly as a component of their normal workday and potentially contact soil with skin; and
 - Inhalation of chemicals in dusts or volatilizing from soil or ground water to outdoor air – Outdoor workers have potential to contact soil dusts or VOCs migrating to the surface through inhalation.
- Outdoor (i.e., construction) Workers
 - Inadvertent ingestion of chemicals in soil – Workers contact surface and subsurface soil directly as a component of their normal workday and potentially ingest soil;
 - Skin contact with chemicals in soil – Workers contact surface and subsurface soil directly as a component of their normal workday and potentially contact soil with skin; and
 - Inhalation of chemicals in dusts or volatilizing from soil or ground water to outdoor air – Outdoor workers have potential to contact soil dusts or VOCs migrating to the surface through inhalation.

The following exposure pathways for the downgradient study area were identified as complete pathways and evaluated for potential risk characterization in the BRA:

- Residents in the Downgradient Study Area
 - Inhalation of chemicals in indoor air - VOCs may be released from subsurface ground water into soil vapor and migrate to the surface and into a residence;

- Inhalation of chemicals in indoor/outdoor air released from lawn irrigation with ground water - VOCs may evaporate from ground water used for irrigation into outdoor air;
- Skin contact, incidental ingestion, and inhalation of chemicals in backyard swimming pools using ground water (children only) - ground water used to fill swimming pools could result in exposure to children through dermal contact, ingestion, and inhalation; and
- Inhalation of chemicals in air released from Walnut Creek surface water - volatilization of VOCs in surface water near residential properties.

2.3.2 *Risk Characterization*

The BRA calculated theoretical estimates of non-cancer and lifetime cancer risks based on the results of exposure and toxicity assessments. Calculated non-cancer and theoretical lifetime cancer risks for individual chemicals were summed for each exposure pathway. For the exposure scenarios (such as ground water used to fill swimming pools) that have multiple exposure pathways (i.e. dermal contact, ingestion, and inhalation), summed risks for each pathway were added together to calculate a cumulative risk calculation for the exposure scenario.

During FS development meetings with the RWQCB, the RWQCB has preliminarily approved the use of theoretical lifetime cancer risk management levels of one in 100,000 (1E-05) for the Hookston Station Parcel (i.e., commercial/industrial/construction workers) and one in 1,000,000 (1E-06) for the downgradient study area (i.e., residents). Theoretical lifetime cancer risks between one in 10,000 (1E-04) and 1E-06 are customary risk management standards that have been deemed acceptable by regulatory agencies, including the USEPA and California EPA.

For non-cancer risk, the USEPA and California EPA have defined that a hazard quotient equal to or less than 1 indicates that adverse non-cancer health effects are unlikely to occur. This hazard quotient will be utilized in this FS as the acceptable non-cancer risk level for all human receptors.

The following subsections, and Tables 2-2 and 2-3, summarize the estimated risks for the exposure scenarios evaluated in the BRA. The reader is referred to the BRA for additional details, including summary tables of calculated potential risks.

2.3.2.1 *Exposure to Chemicals in Indoor Air at the Hookston Station Parcel*

Non-cancer and theoretical lifetime cancer risks were calculated in the BRA for the commercial/industrial worker exposed to VOCs detected in indoor air (TCE and cis-1,2-DCE). The non-cancer risks associated with inhalation of indoor air at the Hookston Station Parcel were not indicative of adverse non-cancer health effects, as indicated by a hazard quotient of less than 1 (Table 2-2). Theoretical lifetime cancer risks associated with inhalation of indoor air were less than $1\text{E-}05$. Therefore, the indoor air pathway at the Hookston Station Parcel is not addressed in this FS.

2.3.2.2 *Exposure to Chemicals in Soil at the Hookston Station Parcel*

Non-cancer and theoretical lifetime cancer risks were calculated in the BRA for the commercial/industrial worker and construction worker exposed to chemicals detected in soil at the Hookston Station Parcel (Table 2-2). Exposure to chemicals in soil was determined to not result in non-cancer health risks to commercial/industrial or construction workers (hazard quotient less than 1).

Commercial/Industrial Worker

Theoretical lifetime cancer risks for the commercial/industrial worker exposed to chemicals of potential concern in soil were $3.1\text{E-}04$; arsenic accounted for 98 percent of the theoretical lifetime cancer risk. These elevated risk values were the result of a relatively small data set (19 data points available at that time) and were skewed high based on two soil samples that exhibited arsenic concentrations well above average. As described above, in May 2006 (after the publication of the BRA), additional soil sampling was completed at the two locations where elevated detections of arsenic were previously identified (B-69 and B-84). The results of that study (presented in Appendix A) did not detect the presence of elevated concentrations of arsenic in surface soils. Because the recent (and more extensive) data identified arsenic concentrations in surface soil that are consistent with regional background levels, the commercial/industrial worker exposure pathway (primarily associated with the ingestion and dermal contact of surface soils) is not addressed within this FS.

Theoretical lifetime cancer risk associated with exposure to TCE in soil was approximately $1.1\text{E-}7$ for a commercial/industrial worker and therefore this pathway is not addressed by this FS.

Construction Worker

Theoretical lifetime cancer risk calculated for the construction worker exposed to chemicals of potential concern in soil was $4.3\text{E-}05$. As with the commercial/industrial worker, this risk is associated primarily with arsenic. As described above, additional arsenic soil sampling was completed at the two locations in May 2006. The results of that study (presented in Appendix A) found concentrations of arsenic above typical background in subsurface soils; elevated arsenic concentrations were not detected in the surface soils. It is believed that the subsurface soils exceed acceptable risk levels for the construction worker scenario, and therefore, this pathway is addressed in this FS.

Theoretical lifetime cancer risk associated with exposure to TCE in soil was approximately $4.8\text{E-}9$ for a construction worker, and therefore this pathway is not addressed in this FS.

2.3.2.3 *Exposure to Chemicals in Indoor Air in the Downgradient Study Area*

Risk calculations for residents in the downgradient study area exposed to VOCs in indoor air were calculated in the BRA for all VOCs detected in indoor air, including those that do not originate from the Hookston Station Parcel (such as PCE and benzene) (Table 2-3). A separate risk calculation was also performed in the BRA for the summed risks of TCE, cis-1,2-DCE, and 1,1-DCE. The theoretical risks were calculated for each residence that participated in the 2004 and 2005-2006 indoor air studies, except three residences that were sampled at the end of the 2005-2006 program. The indoor air results for these residences were not available prior to the submittal of the BRA; the concentrations of VOCs detected in indoor air at these locations were less than the maximum detected concentrations at other residences. The non-cancer risks and theoretical lifetime cancer risks calculated for residents in the downgradient study area are summarized in the BRA.

The RWQCB required evaluating two estimates of exposure and theoretical risk potentially resulting from residents in the downgradient study area inhaling VOCs in residential indoor air. The two estimates utilized different inhalation rates, as described below:

- The first exposure estimate utilized an inhalation rate of 13.3 cubic meters of air per day (m^3/day) for an adult and $8.7 \text{ m}^3/\text{day}$ for a child, as specified in the *Exposure Factors Handbook, Volume I – General Factors* (USEPA 1997); and

- The RWQCB required estimating potential risks utilizing higher inhalation rates (considered by the RWQCB to be upper bound rates) of 20 m³/day for an adult and 10 m³/day for a small child.

In the RWQCB's approval of the BRA (RWQCB 2006a), the RWQCB required the use of the theoretical risks calculated with the higher inhalation rates for preparing this FS. Therefore, only the theoretical risks calculated with the upper bound inhalation rates (the second exposure estimate) are discussed below.

The calculated non-cancer risks for residents in the downgradient study area exposed to all detected VOCs in residential indoor air were less than 1, indicating that exposure to VOCs in indoor air would not result in non-cancer health risks, except at three locations. At these residences, the calculated hazard indices ranged from 1.2 to 1.4 and were mostly attributed to the presence of PCE, benzene, toluene, ethyl benzene, and xylenes in indoor air, which are not chemicals originating from the Hookston Station Parcel.

The calculated theoretical excess lifetime cancer risk for all detected VOCs exceeded 1.0E-06 in 40 homes sampled during 2004 and 2005. The highest calculated theoretical excess lifetime cancer risk from inhalation of all detected VOCs was 8.0E-05. These risks are mostly attributed to detected concentrations of benzene and PCE, which do not originate from the Hookston Station Parcel.

The theoretical cancer risk calculated for TCE, cis-1,2-DCE, and 1,1-DCE exceeded 1.0E-06 in nine homes sampled during 2004 and 2005. The highest calculated theoretical excess lifetime cancer risk from inhalation of TCE, cis-1,2-DCE, and 1,1-DCE was 7.4E-06. Vapor intrusion prevention systems were installed in three of those homes in 2004, resulting in decreased chemical concentrations in indoor air. The calculated theoretical lifetime cancer risk for TCE, cis-1,2-DCE, and 1,1-DCE in those residences is now less than 1.0E-06. Four additional vapor intrusion prevention systems were installed following the 2005 sampling event.

2.3.2.4 *Exposure to VOCs Volatilizing from Ground Water Used for Irrigation in the Downgradient Study Area*

Residents in the downgradient study area are potentially exposed to VOCs volatilizing from ground water obtained from private backyard wells and used for irrigation purposes. As reported in the RI Report, 12 private backyard wells are located within the footprint of the mixed ground water plume in the downgradient study area. Based on the ground water data collected from the private wells, use of the private

wells for irrigation purposes does not pose non-cancer or cancer health risks (hazard quotients less than 1 and theoretical lifetime cancer risks less than 1E-06). The reader is referred to the BRA for potential risk levels calculated for each sampled backyard well. Table 2-3 summarizes the potential risks associated with this exposure scenario.

The RWQCB required evaluating hypothetical exposure and risk associated with using ground water from MW-14A for irrigation purposes. The RWQCB required this evaluation because MW-14A contains the highest TCE ground water concentrations in the downgradient study area. It is important to note that MW-14A is located in the downgradient study area on public land less than 50 feet west of the Hookston Station Parcel property boundary and is only used for ground water monitoring purposes. Therefore, risks calculated for hypothetical users of ground water from MW-14A for irrigation purposes represent “worst case” exposure conditions and is not representative of current exposure conditions. The theoretical non-cancer risk calculated for MW-14A was less than 1 and the theoretical lifetime cancer risk was 6.8E-06 for the irrigation exposure scenario.

2.3.2.5 *Exposure to VOCs Volatilizing from Ground Water Used for Swimming Pools in the Downgradient Study Area*

Residents in the downgradient study area are potentially exposed to VOCs volatilizing from ground water obtained from private backyard wells used for filling swimming pools. Based on the ground water data collected from the private wells, use of the private wells for filling swimming pools does not pose non-cancer or cancer health risks (hazard quotients less than 1 and theoretical lifetime cancer risks less than 1E-06). The reader is referred to the BRA for potential risk levels calculated for each sampled backyard well. Table 2-3 summarizes the potential risks associated with this exposure scenario.

The RWQCB also required evaluating hypothetical exposure and risk associated with using ground water from MW-14A for filling swimming pools. As stated in the previous section, risks calculated for hypothetical users of ground water from MW-14A represent “worst case” exposure conditions, and do not represent current exposure conditions. For this exposure scenario, the theoretical non-cancer risk calculated for MW-14A was 9.4 and the theoretical lifetime cancer risk was 8.1E-06 for hypothetical users of MW-14A ground water.

2.3.2.6 *Exposure to VOCs in Surface Water in the Downgradient Study Area*

Walnut Creek is currently used as part of an engineered storm water drainage network for the Contra Costa County Flood Control District. The creek collects storm water runoff for the Walnut Creek watershed, which encompasses more than 93,500 acres (Dyett & Bhatia 2006), which can obscure the source(s) of chemicals detected in surface water in the creek.

The theoretical lifetime cancer risk for residents exposed to VOCs volatilizing from surface water, regardless of their source, was calculated to be $1.6\text{E-}06$. This risk level was calculated using maximum concentrations of VOCs detected in Walnut Creek during the RI. The majority of the theoretical lifetime cancer risk associated with this exposure pathway was due to concentrations of PCE detected in surface water. As stated previously, PCE is not a chemical that originates from the Hookston Station Parcel. The non-cancer risk hazard quotient was less than 1.

The screening level RA evaluated exposures to ground water as potential surface water within the Walnut Creek canal. In this assessment, ground water and surface water data were compared with appropriate surface water ESLs. That evaluation determined that the surface water concentrations were below even the most stringent surface water ESLs (RWQCB 2003), except one detection of MTBE, indicating that the concentrations of chemicals in surface water would not trigger further investigation or remediation. One detection of MTBE exceeded the surface water ESL, which was selected based on taste and odor thresholds (assumes surface water is used for drinking water), rather than the higher surface water criteria that are based on toxicity values. Similarly, the ground water concentrations reported in monitoring wells closest to the canal are all below the Chronic Aquatic Habitat Goal (RWQCB 2003). Because of these low concentrations below the ESLs, these exposure scenarios were not evaluated further within the BRA, and are not included within this FS.

2.3.3 *Risk Management Thresholds as a Basis for Remedial Action Objectives*

RAOs within this FS (discussed in Section 4) are based on an acceptable theoretical lifetime excess cancer risk level of $1\text{E-}05$ (one in 100,000) for commercial/industrial exposures at the Hookston Station Parcel, and an acceptable theoretical lifetime excess cancer risk level of $1\text{E-}06$ (one in 1,000,000) for residential exposures in the downgradient study area. Non-cancer human health risks will be managed to a Hazard Index of 1 for all exposures. The RWQCB has accepted these risk management thresholds

at similar sites, and Board staff has indicated that these thresholds are appropriate for use in this FS.

RAOs will be developed for completed exposure pathways with calculated theoretical risks above the risk management thresholds. Based on the results of the BRA, RAOs will address:

- Construction worker exposure to arsenic in subsurface soils at the Hookston Station Parcel;
- Residential exposure in the downgradient study area to indoor air containing chemicals that have originated from the Hookston Station Parcel; and
- Residential exposure in the downgradient study area to ground water containing chemicals that have originated from the Hookston Station Parcel.

Although the BRA determined that commercial/industrial exposure at the Hookston Station Parcel to ground water containing chemicals that originated from the Hookston Station Parcel is not a complete pathway (i.e., there are no current uses of ground water at the Hookston Station Parcel), an RAO will be developed that protects potential future users from existing ground water impacts.

A more complete description of RAOs is provided in Section 4.

3.0 PREVIOUS MITIGATION ACTIVITIES AND TECHNOLOGY STUDIES

Several activities have been completed after the completion of the RI and in response to findings of the RA and BRA. These activities are summarized in the following sections.

3.1 VAPOR INTRUSION PREVENTION SYSTEMS

The Hookston RPs installed vapor intrusion prevention systems in three homes in response to the findings of the 2004 indoor air sampling event. TCE results from the 2005/2006 sampling event show that all three homes, which previously exceeded the CHHSL for TCE, now contain concentrations below the screening level. The Hookston RPs offered to install vapor intrusion prevention systems in eight additional homes following the 2005/2006 event; systems have been installed in four of those homes. A monitoring program will be implemented for the homes with vapor intrusion prevention systems.

3.2 BACKYARD WELL ABANDONMENTS

Twelve private backyard wells located within the downgradient study area were identified during the RI. To eliminate potential exposure to impacted ground water, the Hookston RPs have offered to properly decommission (a.k.a. “abandon”) these 12 wells by removing well pumps and electrical systems, followed by pressurized grouting to seal the well from further use. Seven wells have since been abandoned and are no longer used.

3.3 TECHNOLOGY AND AQUIFER STUDIES

To support the preparation of this FS, several remedial technology studies and aquifer tests have been completed. These studies included the following:

- **Laboratory bench-scale chemical oxidation treatability study:** In October 2003, ERM’s Remediation Technology Group in Lawrenceville, New Jersey, conducted a chemical oxidation treatability study of soils collected from the Hookston Station Parcel. The objective of the study was to evaluate the potential effectiveness of two commonly employed oxidants for the constituents of interest at the

Hookston Station Parcel: potassium permanganate and sodium persulfate. The treatability study tested the total soil permanganate demand and the amount of persulfate consumed by soils, in order to assess the ability of these two oxidants to remediate ground water at the Hookston Station Parcel and downgradient study area in a cost effective manner. Soil oxidant demand is one of the greatest factors affecting viability of in situ chemical oxidation. The results of that study are presented in Appendix C.

- **SVE pilot test** - An SVE field pilot test was conducted at the Hookston Station Parcel in April 2006 in order to obtain parameters for evaluating SVE as a potential remedial alternative for the Hookston Station Parcel and downgradient study area. The pilot test utilized one SVE well and three observation wells and consisted of two tests, a step test and a vacuum test. The objectives of these tests were to measure the system performance, determine the soil permeability with respect to air, and determine the radius of influence for the SVE well. Additional information regarding the pilot test methodology, calculations, and results are presented in Appendix E.
- **Aquifer tests** - In April 2006, ERM performed in situ (slug) aquifer tests and two constant-rate discharge tests at the Hookston Station Parcel. Slug tests were performed at 11 monitoring wells (six A-Zone monitoring wells and five B-Zone monitoring wells). Constant-rate pumping tests were conducted in one A-Zone well and one B-Zone well. Aquifer tests were previously performed at the Hookston Station Parcel during Treadwell and Rollo's (T&R) 1993 subsurface investigation. Information regarding ERM's aquifer test methodology and results is included in Appendix G. The methodology and results of the T&R aquifer tests were documented in the report entitled *Subsurface Investigation* (T&R 1993).

This section develops RAOs and cleanup goals to address metals in soil, VOCs in ground water, and VOCs in residential indoor air. The RAOs are based on existing and anticipated future beneficial uses of resources at the Hookston Station Parcel, in light of RI data and risk assessment. The development of RAOs consists of the following steps:

- Identification and evaluation of ARARs that influence the calculation of remedial goals;
- Development of RAOs that are protective of human health and the environment;
- Development of appropriate cleanup goals that incorporate the steps above and are protective of human health and the environment; and
- Identification of the areas requiring remediation.

Each of these steps is described in the following subsections.

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

The *National Oil and Hazardous Substance Pollution Contingency Plan* (Title 40 of the CFR, Part 300 et seq.) requires that remedial actions at CERCLA sites must comply with all ARARs under federal or state environmental laws, public health requirements, or facility citing laws. A requirement may either be “applicable” or “relevant and appropriate” as defined below:

“Applicable requirements are those remedial standards, standards of control, or other environmental protection criteria or limitations that are promulgated under federal or state law that specifically address hazardous substances, pollutants, contaminants, remedial actions, locations, or other circumstances at the site.”

Relevant and appropriate requirements are those promulgated federal and state requirements that, while not applicable to the circumstances at the target site, address problems or situations sufficiently similar to those encountered at other sites that their use is well suited to the target site of concern.

USEPA guidance identifies three categories of ARARs (USEPA 1988a and 1989):

- **Chemical-specific ARARs** are numerical standards set by various regulatory and government agencies that indicate the concentrations of certain compounds permitted in air, soil, ground water, surface water, and sediments;
- **Action-specific ARARs** are generally set performance, design, or other similar action-specific controls or restrictions on site activities related to the management of hazardous substances. Action-specific ARARs will impact all activities that may be performed at the Hookston Station Parcel and downgradient study area; and
- **Location-specific ARARs** are restrictions placed on the conduct of activities solely because they are in specific locations. These ARARs may include restrictions such as those imposed on activities conducted in floodplains or in areas that may experience earthquake activity.

Tables 4-1 to 4-3 identify the chemical-, action-, and location-specific ARARs for this FS.

In addition to the three categories of ARARs listed above, criteria, advisories, and guidance issued by regulatory agencies that are not legally binding may also be considered during the development of remedial alternatives for a site. These items are known as “to be considered” (TBCs) guidelines. TBCs may influence the selection of a remedy to allow the optimal remedy to be identified. Table 4-4 identifies the TBCs for this FS.

4.2 *REMEDIAL ACTION OBJECTIVES*

RAOs consist of chemical- and medium-specific goals for protecting human health and the environment. The RAOs specify the media and contaminants of interest, exposure routes and receptors, and proposed cleanup goals. By specifying both exposure pathways and proposed cleanup goals, the RAOs permit a range of remedial alternatives to be developed in the subsequent sections of the FS.

The media and exposure pathways of concern are those identified in the BRA (Section 2.3) as having associated non-cancer hazards greater than 1 and theoretical lifetime cancer risks above 1E-05 for exposures at the Hookston Station Parcel and above 1E-06 for exposures in the downgradient study area with Hookston Station Parcel chemicals of

concern only (TCE and associated degradation compounds). The existing and potential beneficial uses of ground water and surface water outlined in the Basin Plan (RWQCB 1995) were also factored into this evaluation.

The following RAOs have been developed for the Hookston Station Parcel and downgradient study area:

- Protect human health from incidental ingestion, dermal contact, and inhalation of fugitive dusts from subsurface soil (deeper than 0.5 feet bgs) at the single location on the Hookston Station Parcel having concentrations of arsenic exceeding 1E-05 theoretical lifetime excess cancer risk or background concentrations, whichever is greater.
- Protect human health from possible future consumption or contact with ground water containing chemicals above risk-based cleanup goals that originate from the Hookston Station Parcel by preventing future extraction of VOC-impacted ground water for beneficial uses (e.g., domestic, municipal, or industrial water supply) until the final ground water cleanup goals are achieved.
- Protect human health from potentially impacted indoor air by reducing concentrations of chemicals that originate from the Hookston Station Parcel in indoor air to levels of 1E-06 theoretical lifetime excess cancer risk for carcinogens, or a hazard index of 1 for non-carcinogenic risks. [Note this applies only to the downgradient study area.]
- Achieve restoration of ground water impacted by chemicals that originate from the Hookston Station Parcel for existing and potential beneficial uses (Section 1.3.4).

4.3 *CLEANUP GOALS*

To protect human health and the environment, risk-based cleanup goals were calculated for each completed exposure scenario (Tables 2-2 and 2-3) for soil, ground water, and indoor air that are protective of the risk management thresholds identified in Section 2.3.3. Table 4-5 presents the risk-based cleanup goals; the calculation of these goals is presented in Appendix H. For media with multiple exposure scenarios (e.g., ground water being used for both landscape irrigation and filling of a swimming pool), a cleanup goal was calculated for each scenario. The most conservative risk-based cleanup goal (i.e. the lowest calculated cleanup goal) was selected as the final cleanup goal for media with multiple exposure pathways. The final risk-based cleanup goals selected for the Hookston Station Parcel and downgradient study area impacted by

chemicals that originate from the Hookston Station Parcel are summarized below:

- **Arsenic in subsurface soil at the Hookston Station Parcel:** 31 mg/kg (based on back-calculated 1E-05 risk level for construction worker exposed to subsurface soils, Appendix H); and
- **VOCs in ground water:** California MCLs for drinking water or background water quality, whichever is greater. The current MCLs for chemicals of concern originating from the Hookston Station Parcel are:
 - TCE = 5 µg/L;
 - cis-1,2-DCE = 6 µg/L;
 - trans-1,2-DCE = 10 µg/L;
 - 1,1-DCE = 6 µg/L; and
 - Vinyl chloride = 0.5 µg/L.

As noted above, in addition to the Hookston Station Parcel, several other sources of chemicals of concern have impacted ground water in this region. These non-Hookston Station Parcel sources must also be identified and remediated to assure attainment of the final remedial action objectives in the downgradient study area.

Until the numerous potential contributors to the mixed ground water plume in the downgradient study area have completed their remediation programs (i.e., reduced their contribution to the mixed plume to the MCLs), the cleanup goals for the downgradient study area will be based on background concentrations. For the purposes of this FS, the background concentrations and interim cleanup goals are initially based on the highest concentration of chemicals of concern found within monitoring wells MW-1, MW-4, MW-7, and MW-22A/B. The background concentrations may be refined with time, based on future characterization activities. As stated in Section 2.2, chemicals detected in these wells are not due to a historical TCE release at the Hookston Station Parcel. Although the selected remedy for the Hookston Station Parcel and downgradient study area might potentially treat chemicals that do not originate from the Hookston Station Parcel, the Hookston RPs are not responsible for achieving cleanup of VOC concentrations migrating from other source areas into the downgradient study area. The RWQCB is currently requiring other parties to investigate some of the non-Hookston Station Parcel sources and has stated that they will require those responsible parties

to conduct additional investigation activities and cleanup actions, as necessary (RWQCB 2006b).

- **VOCs in Indoor Air:** The residential indoor air cleanup goals listed below represent concentrations that pose less than or equal to 1E-06 theoretical lifetime excess cancer risk (or a Hazard Index of 1 for non-cancer risks) for residential inhalation, assuming elevated breathing rates in accordance with RWQCB requirements. The calculation of these cleanup goals is presented in Appendix H.
 - TCE = 0.96 µg/m³;
 - cis-1,2-DCE = 63 µg/m³;
 - trans-1,2-DCE = 125 µg/m³;
 - 1,1-DCE = 357 µg/m³; and
 - Vinyl chloride = 0.025 µg/m³.

4.4 AREAS AND VOLUME OF IMPACTED MEDIA

This section identifies the areas for which remedial actions will be necessary in order to meet the RAOs and cleanup goals for the Hookston Station Parcel and downgradient study area.

4.4.1 Soil

As described in Section 2.1.3, activities completed as part of the RI identified two areas at the Hookston Station Parcel of elevated arsenic concentrations in surface soils. Recent sampling completed to support the FS indicated that these two areas do not contain elevated concentrations of arsenic in surface soil, and that one of these areas contains elevated concentrations of arsenic in subsurface soils. Sample location B-69 (A through D), located in the southern portion of the Hookston Station Parcel, contained three subsurface soil samples from 2 feet bgs that exceeded typical background concentrations and the risk-based cleanup goal for arsenic (252 mg/kg arsenic at B-69A, 37.2 mg/kg arsenic at B-69C, and 171 mg/kg arsenic at B-69C).

4.4.2 Ground Water

Ground water within the A- and B-Zones will be addressed within the areas that have been impacted by chemicals originating (in whole or in part) from the Hookston Station Parcel.

Although the long-term goal of the ground water remediation program will be to reduce ground water concentrations to drinking water standards (the MCLs), the near-term focus for ground water will be in areas where indoor air impacts have been observed at concentrations above the indoor air cleanup goals. This area generally coincides with ground water concentrations above approximately 500 µg/L TCE in the downgradient study area. This observed relationship between ground water and indoor air concentrations is consistent with the RWQCB's ground water ESL of 530 µg/L for protection of indoor air impacts. The success reducing breathable indoor air concentrations for the Hookston Station Parcel chemicals of concern will be based on a measurement at the exposure area (i.e., inside the residences).

The area within the 500 µg/L TCE contour interval (based on January 2006 data) in the downgradient study area, which is generally where indoor air impacts above the calculated indoor air cleanup goal (0.96 µg/m³ TCE) have been observed, is approximately 5.5 acres (Figure 2-12).

4.4.3 Indoor Air

Although a portion of the TCE present in residential indoor air may be attributable to other sources, this FS assumes that all homes with indoor air TCE concentrations above the proposed cleanup goal of 0.96 µg/m³ will be addressed in this FS, as shown on Figure 4-1. Based on current data, 11 homes have (at one time) contained TCE concentrations in indoor air above this cleanup goal, and with few exceptions, these homes are located over the core of the mixed plume in the downgradient study area where TCE ground water concentrations are 500 µg/L or greater.. With few exceptions, homes with indoor air concentrations exceeding 0.96 µg/m³ are within the first block of residential homes located between Hookston Road, Hampton Drive, Thames Drive, and Stimel Drive (Figure 4-1). Several of these homes now contain TCE concentrations below the cleanup goal because vapor intrusion prevention systems have been installed.

The objective of this section is to identify and screen available remedial technologies for addressing the affected media defined in Section 4. General response actions (GRAs) that are potentially applicable for achieving RAOs are identified. Remedial technology types and associated technology process options for each GRA are presented. Technology process options are screened to eliminate those that are least suitable for addressing impacted media and achieving RAOs. Technology process options are screened based on the USEPA's screening criteria of effectiveness, implementability, and cost (USEPA 1988b).

5.1

GENERAL RESPONSE ACTIONS

General response actions are broadly defined as general types of actions that can reduce or eliminate the risk that contaminants present to human health and the environment. General response actions are media-specific measures that may be taken to satisfy the RAOs. The GRAs identified for soil, ground water, and/or indoor air include:

- No Action (evaluation required by CERCLA);
- Institutional Controls/Limited Action;
- In Situ Treatment;
- Collection/Ex Situ Treatment;
- Removal; and
- Disposal.

Each of the GRAs (except No Action) can be implemented using a variety of remedial technology types; some technology types include multiple technology process options. General response actions, technology types, and technology process options for soil and ground water are summarized in Tables 5-1 and 5-2, respectively. The remedial technology types and process options were identified based on a variety of reference sources including:

- Remediation Technologies Screening Matrix and Reference Guide, Second Edition, (USEPA 1994).

- USEPA Vendor Information System for Innovative Treatment Technologies (VISITT, Version 5.0).
- Federal Databases:
 - USEPA Technology Innovation Program Remediation Databases.
 - Cleanup Information Bulletin Board (CLU-IN).
 - Risk Reduction Engineering Laboratory (RREL) Treatability Database.
 - Superfund Innovative Technology Evaluation (SITE) Program.
- Literature search on various technical journals and conference proceedings.
- In-house consultant and contractor experience.
- Other consultant reports.
- Treatability studies for other sites.
- Literature survey.

5.2 **SCREENING OF REMEDIAL TECHNOLOGY PROCESS OPTIONS**

This section describes the three USEPA primary screening criteria (effectiveness, implementability, and cost) for remedial technology process options. The remedial technology process options selected for the Hookston Station Parcel are identified in Tables 5-1 and 5-2. These process options are screened against the three criteria in the following sections and also in Tables 5-1 and 5-2. Technology process options that fail to meet one or more of the three criteria are not retained for development of remedial alternatives in Section 6. Table 5-3 summarizes the process options that passed the three criteria screening.

5.2.1 *Screening Criteria*

This subsection describes the components of each of the three primary screening criteria.

5.2.1.1 *Effectiveness*

The effectiveness evaluation focuses on the ability of each technology process option to address contaminants of concern (COCs) and protect

human health and the environment relative to competing options. The effectiveness evaluation is based on the following:

- The ability of a technology process option to achieve the desired cleanup goal for each contaminant of concern (described in Section 4.3) and handle the specified areas and volumes (described in Section 4.4);
- The degree of protectiveness to human health and the environment provided by the technology process option during construction and implementation; and
- The reliability of the technology process option with respect to the contaminants and site conditions.

5.2.1.2 *Implementability*

The implementability evaluation focuses on the technical and administrative feasibility of a technology process option. The implementability evaluation is based on the following:

- The institutional aspects of implementation, including the ability to obtain necessary permits and general public acceptance; and
- The availability of support services and equipment, and the degree to which the technology process option has been demonstrated at other sites.

5.2.1.3 *Cost*

This criterion is used to compare the capital and operation and maintenance (O&M) costs of the technology process options. Cost plays a limited role in the screening of process options relative to the two previous criteria. Relative capital and O&M costs are used rather than detailed estimates. Relative costs are determined based on engineering judgment, and each option is evaluated as to whether costs are expected to be low, medium, or high relative to other options.

5.2.2 *Screening of Technology Process Options*

The screening evaluation of remedial technology process options for soil, ground water, and indoor air is summarized in Tables 5-1 and 5-2. Based on the screening, those technology process options least suitable for addressing impacted media and achieving RAOs were eliminated. Those technology process options considered potentially technically effective, implementable given current knowledge of the Hookston Station Parcel and downgradient study area, and cost-effective relative to competing

options were retained. Table 5-3 lists the retained technologies for soil, ground water, and indoor air remediation. These retained technologies are carried forward to Section 6 where remedial alternatives are developed.

5.3 *DESCRIPTION OF RETAINED TECHNOLOGIES*

This section presents a more complete description of the technologies retained following the screening process above. The technologies described in this section are the primary treatment technologies used in the remedial alternatives developed in Section 6.

5.3.1 *Institutional Controls*

The use of institutional controls as a remedial process involves placing restrictions on the current and future uses of the land and ground water impacted by contaminants. The institutional control components retained for use in developing remedial alternatives include restricting land and water use through deed notifications and restrictions. Deed notifications and/or restrictions create legal restrictions on specific activities or uses of land or water by current and future landowners. These restrictions are intended to prevent unauthorized development of the land and water and to protect workers at the Hookston Station Parcel through notification of contamination and instruction on proper work procedures to prevent exposure.

5.3.2 *Vapor Intrusion Prevention Systems*

Vapor intrusion prevention systems eliminate the migration of VOCs into the indoor living space of residences located above the contaminated area. The components of this technology generally consist of both:

- Placement of a vapor barrier either on the soil under residences or on the underside of the floor structure to prevent migration of vapor up into the residence; and
- Low flow vapor extraction performed under the vapor barrier using small, low-vacuum blowers.

5.3.3 *Private Well Removal*

The use of private well removal as a remedial technology involves decommissioning existing private wells, such as the irrigation wells present at a limited number of residences within the downgradient study

area, to eliminate the risk pathway associated with use of the wells and to prevent downward migration of contaminants within the wells. This technology involves decommissioning individual wells using standard well-closure procedures. If the private wells are currently being used as a water supply, the existing public water supply at the residence would be retrofitted to provide service to the disconnected components. This technology requires cooperation by property owners to allow removal of the well.

5.3.4 *Monitored Natural Attenuation*

Monitored Natural Attenuation (MNA) is one option for a long-term mechanism to achieve ground water RAOs. Natural attenuation processes include a variety of physical, chemical, and/or biological processes that act without human intervention to reduce the mass or concentration of contaminants in soil and ground water. Natural attenuation depends on geologic and hydrogeologic characteristics of the aquifer, the physical and chemical properties of the soil, and the metabolic capabilities of native microbes. Natural attenuation comprises several mechanical, physicochemical, and biological processes as follows:

- Mechanical processes including molecular diffusion, mechanical dispersion, and dilution from recharge;
- Physicochemical processes including sorption of the contaminant to the aquifer matrix, hydrolysis, precipitation of the contaminant as an insoluble solid, and volatilization; and
- Biological processes whereby contaminants are degraded by microorganisms in the aquifer and destroyed through use as a primary energy source, use as an electron acceptor by reductive dechlorination, or cometabolization with another energy source.

5.3.5 *Enhanced Anaerobic Bioremediation*

Enhanced anaerobic bioremediation of chlorinated ethenes, such as TCE, involves the stimulation of the natural biological process of reductive dechlorination through the addition of a carbon source that, upon utilization by microbes, results in the stimulation of the microbial population and generation of hydrogen and reducing conditions. The resulting anaerobic conditions are more favorable for reductive dechlorination by the same mechanisms described above for natural attenuation, but at a much more accelerated rate. In some cases, organisms may need to be added, but only if the natural microbial population is incapable of performing the required transformations.

The amendment used to stimulate and enhance bioremediation can include a wide range of products, such as soluble substrates consisting of aqueous solutions of lactate, low-viscosity mixtures of materials including emulsified oils, and high-viscosity pure oils. Aqueous solutions have the benefit of being able to be readily injected in large volumes to increase distribution, but rely on repeated injections to maintain appropriate concentrations of the amendments. Low viscosity liquids can be injected at nearly the rate of soluble products with the added benefit of longer lasting effects. High-viscosity fluids are difficult to inject in large volumes but have the benefit of very long-lasting reactivity. The amendments may also include bacterial cultures to ensure chlorinated ethenes can be completely degraded (known as “bioaugmentation”).

Enhanced anaerobic bioremediation is a well known remedial technology for treatment of CVOCs. However, there are also known short-comings of this technology, due to the need to rely on natural degradation processes within the subsurface. In addition, heterogeneities or preferential flow paths can limit distribution of amendments in the subsurface. The primary concern of this technology is the incomplete dechlorination of TCE to DCE and subsequently to vinyl chloride. Vinyl chloride has been shown to be recalcitrant to biodegradation under some conditions, which may leave the degradation of TCE incomplete. This typically results in increased risk to receptors, particularly if indoor air is a primary risk pathway, as vinyl chloride is both more volatile and more toxic than TCE. Implementation of this technology would require bench and pilot testing to evaluate the completeness of the reductive dechlorination, to determine the most effective amendment, and to assess the need for bioaugmentation.

Implementation of enhanced anaerobic bioremediation would consist of injection of the selected amendment using the most appropriate injection technique. This may include direct-push boreholes, where open space is available for large number of points. Figure 5-1 presents a conceptual view of a direct-push injection setup. Dedicated injection wells provide the ability to periodically inject much larger volumes at a limited number of wells, where space is too limited for use of direct-push points.

5.3.6

In Situ Chemical Oxidation

One of the most common mechanisms for the in situ chemical treatment of VOCs is oxidation. In situ chemical oxidation involves the placement of an oxidant into the subsurface to directly react with the contaminants. The potential benefits from in situ oxidation include in situ contaminant destruction, relatively low cost, reliability, simplicity, and rapid treatment. However, site-specific constraints must be considered. Efficient oxidation

is dependent on the contact between oxidant and contaminant. Subsurface heterogeneities, preferential flow paths, and a high level of organic material may result in inefficient treatment. This is the primary reason why chemical oxidation has been retained only for B-Zone ground water, with its higher conductivity and low oxidant demand.

One of the most common oxidants available for use in the chemical treatment of chlorinated ethenes is potassium permanganate. Delivered to the treatment zone as a dilute (up to 5 percent) solution, permanganate ions cause the solution to turn purple, which provides a visual indicator of the chemical's distribution and activity in ground water. When the permanganate is reduced upon reaction with organic matter, it forms manganese dioxide. Because potassium permanganate is delivered as a dilute solution, it is a relatively safe oxidant to use, while other oxidants, such as hydrogen peroxide (used alone or as a component of the Fenton's Reagent reaction) can generate a significant amount of heat and pressure during implementation. Sodium permanganate is used similarly to potassium permanganate, but is available as a higher concentration solution. This makes sodium permanganate an appropriate alternative to potassium permanganate where a higher concentration reagent is required.

The primary delivery mechanism for in situ chemical oxidation involves the placement, through fluid injection, of the oxidizing material in the zone of contaminated ground water being treated. At the Hookston Station Parcel, chemical oxidation would be expected to be performed using either direct-push injection or injection through dedicated injection wells. Figure 5-1 presents a conceptual view of a direct-push injection setup. The soluble nature of the permanganate ion allows relatively simple injection. Health and safety precautions must be implemented to prevent injury to workers and the public during the application of this technology.

5.3.7 *Zero-Valent Iron Permeable Reactive Barrier*

Permeable reactive barriers (PRBs) are a relatively innovative technology that provides treatment of dissolved contaminants as ground water flows through the PRB, which is installed across the water-bearing zone to be treated. PRBs have applicability for many contaminant groups, including CVOCs such as TCE.

The PRB is developed by placing a zone of reactive material in the path of ground water flow. Figure 5-2 presents a conceptual view of the treatment of ground water using a PRB. The zone of reactivity must be designed using parameters such as contaminant concentrations, ground

water flow velocity, and other hydrogeologic parameters. The reactive medium used for PRBs treating CVOCs is zero-valent iron, which is oxidized once it is added to the reaction cell. The resulting electron activity results in nearly immediate reductive dechlorination of the chlorinated ethenes. The resulting products are relatively harmless chloride ions and ethane. Ethane itself is readily degraded under natural conditions in most aquifer systems.

The two primary installation methods being considered for the PRBs in the remedial alternatives described in Section 6 are trenching and direct injection. Placement of zero-valent iron in a PRB has been commonly performed by trenching in areas where a continuously-excavated trench is possible. The trenching can be performed using several methods, including standard backhoe trenching for shallow trenches, clamshell excavation for very deep trenches, and excavation with a continuous trencher for fast trench installation. The continuous trencher is the most applicable trench installation method installing relatively shallow PRBs. This method uses a chain-saw type apparatus on a heavy crawler-mounted vehicle to dig a narrow, continuous trench while simultaneously placing the reactive wall material as the trencher advances. This method can install reactive material at a faster rate and is more cost effective, relative to the other trenching methods, but can only install PRBs in areas lacking subsurface obstructions, such as underground utilities. This would be the preferred PRB installation method for the Hookston Station Parcel, but may be determined to be infeasible due to the extent of subsurface utilities.

The other PRB installation method that would be further examined is direct injection of zero-valent iron. Direct injection has been performed using several methods, some of which are proprietary methods specific to individual contractors. The primary direct injection methods reviewed during this FS are hydraulic fracturing and jetting. These methods involve injecting iron in a powder or granular form or as a gel or slurry mixture of iron and a biodegradable substrate. The material is injected at a high pressure to either create fractures that are filled with the injected iron mixture (hydraulic fracturing) or to erode the subsurface soil enough to mix the injected iron with the soil (jetting). These installation methods are less likely to be affected by subsurface utilities than traditional trenching methods.

5.3.8

Ground Water Extraction, Treatment, and Disposal

Ground water extraction, treatment, and disposal, commonly referred to as pump and treat, is a set of traditional technologies and process options for ground water remediation through contaminant migration control and

contaminant mass removal methods. While several process options are available to extract ground water from the subsurface (trenches, horizontal piping, vacuum systems, etc.), the process option identified and screened for the Hookston Station Parcel, based on site-specific conditions, involves the use of traditional vertical ground water pumping wells placed at specific locations to ensure capture of contaminated ground water. Dissolved VOCs would be captured via pumping, conveyed to a central treatment system, physically or chemically treated, and disposed of through the sanitary sewer system. Figure 5-3 presents a conceptual view of the components of a typical ground water extraction, treatment, and disposal system.

In this section, the technologies and process options that were retained through the initial screening in Section 5 are combined into workable remedial systems (alternatives) that address the RAOs developed in Section 4. General response actions and the process options chosen to represent the various technology types are combined to form several alternatives for the Hookston Station Parcel and downgradient study area as a whole.

Section 6.1 describes the general approach used to assemble media and areas for the development of remedial alternatives. Section 6.2 introduces the methodology used to estimate remedial timeframes for each component of the remedial alternatives. Section 6.3 describes the components that are common to all of the “active remediation” alternatives (i.e., all of the remedial alternatives with the exception of No Action). The sections that follow present the remedial action alternatives developed for the affected media at the Hookston Station Parcel and downgradient study area.

The remedial alternatives developed in this section are based on conceptual-level designs for the implementation of the screened remedial technologies described in Section 5. The design parameters used to develop the remedial alternatives are based on engineering judgment, knowledge of current conditions at the Hookston Station Parcel and downgradient study area, the performance of pilot studies, and ground water modeling.

The remedial alternatives have been developed to meet the RAOs developed in Section 4.2, as well as the requirements of Section 430 of the *National Oil And Hazardous Substances Pollution Contingency Plan* (NCP) (40 CFR 300.430), which stipulates the FS remedy selection process. The NCP requires that the FS evaluate:

- A range of remedial alternatives in which treatment that reduces the toxicity, mobility, or volume (TMV) of hazardous substances, pollutants, or contaminants is a principal element. As appropriate, this range shall include an alternative that removes or destroys hazardous substances, pollutants, or contaminants to the maximum extent feasible, eliminating or reducing, to the degree possible, the need for long-term management; and

- One or more remedial alternatives that involve little or no treatment, but provide protection of human health and the environment primarily by preventing or controlling exposure to hazardous substances, pollutants, or contaminants through engineering controls.

6.1 ***MEDIA AND AREAS CONSIDERED***

Areas of impacted media were identified in Section 4.4 based on the RAOs and exceedances of cleanup goals. These are areas for which technologies and process options are selected to comprise each remedial alternative. The areas for which remedial alternatives have been developed are:

- Soil;
- A-Zone Ground Water;
- B-Zone Ground Water; and
- Residential Indoor Air.

These areas are described in the following sections.

6.1.1 ***Soil***

As described in Section 4.4.1, sampling activities have indicated the presence of arsenic in subsurface soil at levels exceeding risk to industrial and/or construction workers. This is based on limited detections of arsenic above the acceptable risk-based concentration (31 mg/kg) in subsurface soil (deeper than 0.5 feet bgs) in the vicinity of sampling location B-69.

6.1.2 ***A-Zone Ground Water***

As discussed in Section 4.4.2, the area of A-Zone ground water addressed in this FS includes areas within the Hookston Station Parcel and the downgradient study area that have been impacted in whole or in part by chemicals originating from the Hookston Station. The A-Zone downgradient study area is the area of A-Zone ground water downgradient of the Hookston Station Parcel impacted by VOCs at concentrations exceeding cleanup goals described in Section 4.3, that have originated from the Hookston Station Parcel.

6.1.3 *B-Zone Ground Water*

Similar to A-Zone ground water, the area of B-Zone ground water addressed in this FS includes areas within the Hookston Station Parcel and downgradient study area that have been impacted in whole or in part by chemicals originating from the Hookston Station Parcel. The B-Zone downgradient study area is the area of B-Zone ground water downgradient of the Hookston Station Parcel impacted by VOCs at concentrations exceeding cleanup goals described in Section 4.3, that have originated from the Hookston Station Parcel.

6.1.4 *Residential Indoor Air*

The residential indoor air pathway addressed by this FS is limited to exposure to indoor air in residences that generally overlay the portion of the A-Zone downgradient study area that contains TCE at concentrations of 500 µg/L or greater. The remedial alternatives described in this section include remedies for indoor air where impacts have been observed, or are expected to be observed based on a home's location relative to the ground water plume.

6.2 *REMEDATION DURATION ESTIMATES*

In order to accurately estimate relative cost for each of the remedial alternatives, treatment durations (i.e., the time required to meet cleanup goals) were estimated for each individual technology. Remedial timeframes are a critical component of the detailed and comparative analysis of the remedial alternatives presented in Section 7. Remedial timeframes directly influence the evaluation of several of the criteria, most notably overall protection of human health and the environment, short-term effectiveness, and cost.

Appendix I describes details on the modeling methodology that was used to estimate timeframes for each of the active remedial alternatives. The estimated durations used in this FS are based on calculated or measured contaminant decay rates, experience with the technologies at similar sites, modeling, and engineering judgment.

6.3 *THREE COMPONENTS COMMON TO "ACTIVE REMEDIATION" ALTERNATIVES*

Six remedial alternatives have been developed for the Hookston Station Parcel (discussed further in Section 6.4). Remedial Alternative 1 is the No

Action alternative, which is required by the NCP. Remedial Alternatives 2 through 6 are “active remediation” alternatives and include several presumptive remedies and mitigation measures that are common to each of these five remedial alternatives. The three common components include:

- Institutional controls for arsenic-impacted subsurface soil in the form of a Soil Management Plan (SMP);
- Vapor intrusion prevention components for residences in the downgradient study area in which TCE is present in indoor air at concentrations that exceed the associated indoor air cleanup goals; and
- Removal of private wells, which are used for irrigation and filling swimming pools, from residences that overlie the commingled plume in the downgradient study area.

These components are described in the following sections. Additional components associated with Remedial Alternatives 2 through 6 that are not common to all five of these remedial alternatives are discussed in Section 6.4.

6.3.1

Soil Management Plan for Arsenic in Soil

Soil that contains arsenic concentrations above the applicable cleanup goal is limited to subsurface soil (deeper than 0.5 feet bgs) on a small portion of the Hookston Station Parcel. Risks to human health associated with the arsenic in soil are limited to construction workers that may be exposed to the soil during invasive activities at the Hookston Station Parcel. Because of the limited scale and risk of the contamination, arsenic-impacted soil is expected to be left in place. Therefore, the soil that is impacted by arsenic does not warrant full evaluation of alternative technologies.

Under Remedial Alternatives 2 through 6, arsenic-impacted soil would be addressed through the use of institutional controls. An SMP would be developed to provide standard procedures for subsurface work at the Hookston Station Parcel that may expose soil containing concentrations of arsenic above background levels. The SMP would include procedures for determining the presence of arsenic within the work zone, as well as procedures for protecting workers through monitoring and protective equipment. In addition, the SMP would provide procedures for proper management of arsenic-impacted soil, if encountered during subsurface work at the Hookston Station Parcel. Enforcement of the SMP would be accomplished through a deed restriction and notification that will link the SMP to ownership of the Hookston Station Parcel.

6.3.2

Vapor Intrusion Prevention Systems

Remedial Alternatives 2 through 6 include the use of vapor intrusion prevention systems to prevent exposure to VOCs in residential indoor air in the downgradient study area. It is expected that residential buildings present within the footprint of the ground water plume that contains TCE at concentrations greater than 530 µg/L would undergo voluntary indoor air sampling to evaluate the extent of indoor air impacts to determine which residences require mitigation. Based on data collected to date from residences with crawl-space vapor prevention systems, the use of vapor intrusion prevention components implemented at other individual residences impacted by TCE in indoor air is expected to be an effective method of reducing the risks associated with this pathway. This technology is expected to be a cost-effective and low-impact method of intercepting TCE prior to reaching indoor air.

Installation of the vapor intrusion prevention systems would consist of installation of a vapor barrier on the soil under residences to prevent migration of vapor up into the residence. Under the vapor barrier, low flow vapor extraction would be performed as an enhancement to the vapor barrier. The low flow extraction would enhance the removal of TCE and degradation products from soil vapor.

Annual maintenance or inspection of the system components would also be performed. It is expected that operation of the systems would be required for approximately 1 year beyond the point at which TCE in A-Zone ground water is treated to below the concentration at which indoor air impacts are expected (530 µg/L screening level described in Section 4.4.2), based on the installation of 20 vapor prevention systems. This 1-year period allows soil vapor to be flushed of TCE to the point at which the vapor intrusion risk pathway is mitigated. The modeling contained in Appendix I presents the estimated time frame for each of the remedial alternatives to reach the 530 µg/L concentration.

6.3.3

Private Well Removal

A limited number of residences located within the footprint of the downgradient study area have private extraction wells used to provide water for landscape irrigation and filling swimming pools. In order to reduce the potential risks posed by use of VOC-impacted ground water for pool filling, as described in Section 2.2, Remedial Alternatives 2 through 6 include decommissioning of private wells located within the footprint of the downgradient study area. Because the construction of these wells is unknown, this action also serves to eliminate potential cross-contamination between various aquifer units. The systems supplied by

the private wells would be connected to the existing public water system. Due to the small number of residences with private wells, the expected varying degree of construction required for completion of the re-plumbing, and the consistency of inclusion of this component in the five remedial alternatives with other associated costs, this component was not included in the cost estimates for Remedial Alternatives 2 through 6.

6.4 DESCRIPTION OF REMEDIAL ALTERNATIVES

The following sections provide descriptions of each of the remedial alternatives. A summary of each remedial alternative is provided in Table 6-1. These remedial alternatives are compared to one another in Section 7 to select a final remedy for implementation.

6.4.1 Remedial Alternative 1

Remedial Alternative 1 is the No Action alternative. No action would be taken under this remedial alternative to address COCs in all impacted areas and media. Under this remedial alternative, no remediation, monitoring, or engineering and institutional controls would be implemented. Ground water monitoring would be discontinued, and no tracking of plume stability or migration would be conducted. The inclusion and evaluation of the No Action alternative is required by the NCP to serve as a baseline against which the performance of other alternatives is evaluated. A conceptual view of the impacted areas and the respective lack of treatment components for these areas are presented on Figure 6-1.

6.4.2 Remedial Alternative 2

Remedial Alternative 2 would leave COCs in place while institutional controls and natural degradation processes are utilized to reduce contaminant TMV.

Table 6-1 lists the components of Remedial Alternative 2. Figure 6-2 presents a conceptual cross-sectional view of the components of Remedial Alternative 2. Figure 6-3 presents a plan view of the components of Remedial Alternative 2, which include:

- MNA of A- and B-Zone ground water; and
- The common remedial alternative components described in Section 6.3.

These components are discussed in the following paragraphs.

6.4.2.1 *A- and B-Zone Ground Water*

As part of this remedial alternative, TCE in A- and B-Zone ground water would be addressed using MNA. Implementation of MNA at Hookston Station would generally involve the following:

- Preparation of an MNA work plan;
- Installation of 20 new nested A- and B-Zone monitoring wells at the locations depicted on Figure 6-3;
- Collection of ground water samples at 60 monitoring wells for VOCs and 30 wells for geochemical indicators of MNA for 30 or more years according to the following schedule:
 - Quarterly sampling during years 1 through 5,
 - Semi-annual sampling during years 6 through 10, and
 - Annual sampling during years 11 through 30, and;
- Abandonment of the monitoring wells at the conclusion of the program.

6.4.2.2 *Common Remedial Alternative Components*

This remedial alternative also includes the three common components of Remedial Alternatives 2 through 6 described in Section 6.3. These three components are the SMP for arsenic-impacted soil on the Hookston Station Parcel, vapor intrusion prevention systems for residences as necessary, and private well closures. This remedial alternative is expected to require operation of the vapor intrusion prevention systems for 30 years or more. For costing purposes, a duration of 30 years was used.

6.4.3 *Remedial Alternative 3*

Remedial Alternative 3 incorporates active ground water remediation in A- and B-Zone ground water in addition to the components of Remedial Alternative 2. Table 6-1 outlines the components of Remedial Alternative 3 and Figure 6-4 presents a conceptual cross-section view of the components. Figures 6-5 through 6-8 present conceptual views of the proposed remedial systems.

Remedial Alternative 3 consists of the following components:

- Enhanced bioremediation of A-Zone ground water;

- Chemical oxidation of B-Zone ground water; and
- The three common remedial alternative components discussed in Section 6.3.

6.4.3.1 *A-Zone Ground Water*

Under this remedial alternative, enhanced anaerobic bioremediation would be implemented to address VOCs in A-Zone ground water on both the Hookston Station Parcel and the downgradient study area. Treatment by enhanced anaerobic bioremediation would consist of injection of an amendment to promote reductive dechlorination of TCE. The treatment performed within the Hookston Station Parcel would consist of direct-push injections of the amendment. Treatment in the downgradient study area would consist of a row of dedicated injection wells placed perpendicular to ground water flow direction to provide treatment under adjacent residential blocks.

The amendment used to stimulate and enhance bioremediation may include products commonly used for inducing accelerated reductive dechlorination, such as emulsified soybean oil or lactate mixtures. The amendments may also include bacterial cultures to ensure chlorinated ethenes can be completely degraded (i.e. bioaugmentation). For the purpose of developing a cost estimate for this component of Alternative 3, the use of an emulsified soybean oil without the need for bioaugmentation was assumed.

The treatment provided by this alternative is expected to reduce concentrations of TCE to below the level at which indoor air impacts would be expected in a period of 5 years, allowing operation of the vapor intrusion prevention systems to cease after approximately 6 years. The estimated period for the bioremediation system to result in achievement of RAOs applicable to the downgradient study area is likely to be 30 years or greater (achieving ground water MCL). The period to achieve RAOs applicable to the Hookston Station parcel using bioremediation is expected to be approximately 10 years.

Following completion of the active remediation by enhanced anaerobic bioremediation, further long-term reduction of VOCs in A-Zone ground water would be accomplished through residual biological activity, as well as other natural degradation processes.

Figure 6-5 presents an overview of the area of enhanced anaerobic bioremediation treatment in A-Zone ground water. Figure 6-6 presents the layout of A-Zone direct-push injection points within the Hookston

Station Parcel and Figure 6-7 presents the layout of dedicated injection wells in the downgradient study area.

Implementation of the enhanced anaerobic bioremediation alternative for A-Zone ground water would generally involve:

- Preparation of a remedial action work plan and obtaining appropriate permits;
- Performance of bench testing and pilot testing to evaluate optimal amendment mixture specifications and volume required to achieve cleanup goals;
- Installation of 10 A-Zone ground water monitoring wells to evaluate performance of this remedial action (Figure 6-5);
- Direct-push injection on the Hookston Station Parcel of the selected amendment mixture in rows oriented perpendicular to ground water flow with a 20-foot spacing between injection points within the row and with 60-foot spacing between rows (Figure 6-6);
- Installation of eight dedicated injection wells screened within the A-Zone in the downgradient study area across the width of the commingled ground water plume containing concentrations of 500 µg/L or greater TCE (Figure 6-7);
- Injection of the selected amendment mixture at the dedicated injection wells;
- Repeated amendment injections as needed to maintain appropriate carbon source concentrations and required reducing conditions (expected to be approximately annually) for approximately 3 years on the Hookston Station Parcel and 10 years in the downgradient study area;
- Collection and analysis of ground water samples from the Hookston Station Parcel at approximately 15 A-Zone monitoring wells for VOCs and eight A-Zone monitoring wells for geochemical parameters for 10 years according to the following schedule:
 - Quarterly sampling during years 1 through 5, and
 - Semi-annual sampling during years 6 through 10;
- Collection and analysis of ground water samples from the downgradient study area at approximately 15 A-Zone monitoring

wells for VOCs and eight A-Zone wells for geochemical parameters for 30 years or more according to the following schedule:

- Quarterly sampling during years 1 through 5,
- Semi-annual sampling during years 6 through 10, and
- Annual sampling during years 11 through 30; and
- Abandon the monitoring wells at the conclusion of the program.

6.4.3.2

B-Zone Ground Water

Under this remedial alternative, chemical oxidation would be implemented to address VOCs in B-Zone ground water. This remedial alternative assumes that an oxidant would be applied in a limited area of approximately 60,000 square feet surrounding the area where TCE concentrations are highest.

As documented in the 18 June 2003 evaluation by ERM's Remedial Technology Center (Appendix C), the most promising oxidant for this application is potassium permanganate. Bench testing determined that soil oxidant demand for potassium permanganate was 0.5 to 1 pound per cubic yard of B-Zone soil, which is considered a "low" oxidant demand, and that the use of potassium permanganate could be cost-effectively implemented based on the chemistry. It should be noted that alternative oxidants may be used based on evaluations of other oxidation products and the results of pilot testing, but for the purposes of this FS, the use of potassium permanganate has been assumed.

Based on the impacted area size, soil oxidant demand, and chemical demand, it is estimated that approximately 32 tons of solid potassium permanganate powder would be required to treat TCE present in the B-Zone. The powder would be mixed at the Hookston Station Parcel with tap water to produce a 3-percent solution. The oxidant solution would be introduced into the subsurface by pressure injection using direct-push drilling techniques. Angled injection techniques would be used to deliver oxidant beneath existing buildings. Based on a target goal of 5-percent soil pore volume displacement, each event would require injection of 560 gallons of 3-percent solution at 150 injection points, distributed around the highest concentration B-Zone ground water on 20-foot centers. To promote lateral distribution, the solution is planned to be injected over three injection events. The potential layout of the potassium permanganate injection points are shown on Figure 6-8.

Reduction of VOCs to RAOs would occur through the significant mass removal achieved by chemical oxidation and natural degradation processes.

Implementation of chemical oxidation for B-Zone ground water would generally involve:

- Preparation of a remedial action work plan and obtaining appropriate permits;
- Performance of a pilot test to evaluate optimal permanganate dosage, volume, and injection pressures required to achieve cleanup goals;
- Installation of 10 B-Zone ground water monitoring wells to evaluate performance of this remedial action (Figure 6-5);
- Performance of three injection events over a 6-month period. Each event would include injection of 560 gallons of 3-percent solution at 150 injection points (Figure 6-8);
- Collection of ground water samples at approximately 30 B-Zone monitoring wells for VOCs and 15 B-Zone wells for geochemical parameters for 30 years according to the following schedule:
 - Quarterly sampling during years 1 through 3,
 - Semi-annual sampling during years 4 through 8, and
 - Annual sampling during years 9 through 30; and
- Abandonment of the monitoring wells at the conclusion of the program.

6.4.3.3 *Common Remedial Alternative Components*

This remedial alternative also includes the three common components of Remedial Alternatives 2 through 6 described in Section 6.3. These three components are the SMP for arsenic-impacted soil on the Hookston Station Parcel, vapor intrusion prevention systems for residences as necessary, and private well closures. The use of enhanced bioremediation in the downgradient study area reduces the required duration of the vapor intrusion prevention to approximately 6 years.

6.4.4 *Remedial Alternative 4*

Remedial Alternative 4 incorporates many components of Remedial Alternatives 2 and 3, while utilizing a reactive barrier technology for treatment of VOCs in A-Zone ground water. Table 6-1 outlines the components of Remedial Alternative 4. Figure 6-9 presents a conceptual cross-section view of the components of Remedial Alternative 4, while Figures 6-10 and 6-11 present a conceptual view of the proposed remedial systems.

Remedial Alternative 4 consists of the following components:

- Zero-valent iron PRB for A-Zone ground water;
- Chemical oxidation for B-Zone ground water; and
- The three common remedial alternative components discussed in Section 6.3.

6.4.4.1 *A-Zone Ground Water*

This remedial alternative would consist of installation of a zero-valent iron PRB to provide treatment of A-Zone ground water. The PRB would be installed in a location in the downgradient study area capable of treating ground water prior to flowing beneath the downgradient residences that have been impacted by vapor intrusion. The treatment provided by the PRB is expected to reduce concentrations of TCE to below the level at which indoor air impacts would be expected in a period of 3 years, allowing operation of the vapor intrusion prevention systems to cease after approximately 4 years. The estimated period for the PRB to result in achievement of RAOs applicable to the downgradient study area is likely to be greater than 30 years (achieving ground water MCL). The proposed location of the PRB is presented on Figure 6-10. Implementation of this remedial action alternative for A-Zone ground water would generally involve:

- Preparation of a remedial action work plan and obtaining appropriate permits;
- Performance of bench column testing to develop specifications for the PRB;
- Installation of 10 A-Zone ground water monitoring wells to evaluate performance of this remedial action (Figure 6-10);

- Installation of the permeable reactive barrier, consisting of an approximately 500-foot long and 40-foot deep placement of zero-valent iron within a dug trench or using slurry injection techniques;
- Collection of ground water samples at 30 A-Zone monitoring wells for VOCs and 15 A-Zone monitoring wells for geochemical parameters for 30 years or greater according to the following schedule:
 - Quarterly sampling during years 1 through 5,
 - Semi-annual sampling during years 6 through 10, and
 - Annual sampling during years 11 through 30; and
- Abandonment of the monitoring wells at the conclusion of the program.

6.4.4.2 *B-Zone Ground Water*

Under this remedial alternative, chemical oxidation would be implemented to address VOCs in B-Zone ground water as shown on Figure 6-11. The implementation of this component of Remedial Alternative 4 is proposed as described for Remedial Alternative 3, in Section 6.3.3.

6.4.4.3 *Common Remedial Alternative Components*

This remedial alternative also includes the three common components of Remedial Alternatives 2 through 6 described in Section 6.3. These components are the SMP for arsenic-impacted soil on the Hookston Station Parcel, vapor intrusion prevention systems at residences as necessary, and private well closures. The use of the A-Zone PRB reduces the required duration of the vapor intrusion prevention systems to approximately 4 years.

6.4.5 *Remedial Alternative 5*

Remedial Alternative 5 incorporates many of the components of Remedial Alternative 4 with the exception that B-Zone ground water is treated using a PRB installed similar to the A-Zone ground water PRB discussed above for Remedial Alternative 4. Table 6-1 outlines the components of Remedial Alternative 5. Figure 6-12 presents a conceptual cross-section view of the components of Remedial Alternative 5. Figure 6-13 presents a conceptual plan view of the proposed remedial systems.

Remedial Alternative 5 consists of the following:

- PRB for A-Zone ground water;
- PRB for B-Zone ground water; and
- The three common remedial alternative components discussed in Section 6.3.

6.4.5.1 *A- and B-Zone Ground Water*

This remedial alternative would consist of installation of a zero-valent iron PRB to provide treatment of A- and B-Zone ground water. The PRB would be installed in the downgradient study area in a location capable of treating ground water prior to flowing beneath the downgradient residences. Since the PRB would be installed to the bottom of the B-Zone, at a depth up to 70 feet bgs, a high-pressure injection method would be required to place the zero-valent iron across the two water-bearing zones.

The treatment provided by the PRB is expected to reduce concentrations of TCE to below the level at which indoor air impacts would be expected in a period of 3 years, allowing operation of the vapor intrusion prevention systems to cease after approximately 4 years. The estimated period for the PRB to result in achievement of all RAOs is likely to be greater than 30 years (achieving ground water MCL). The proposed location of the A- and B-Zone PRBs is presented on Figure 6-13. Implementation of this remedial action alternative for A- and B-Zone ground water would generally involve:

- Preparation of a remedial action work plan and obtaining appropriate permits;
- Performance of bench column testing to develop specifications for the PRB;
- Installation of 20 A- and B-Zone ground water monitoring to evaluate performance of this remedial action (Figure 6-13);
- Installation of the permeable reactive barrier, consisting of an approximately 500-foot long and 70-foot deep placement of zero-valent iron using slurry injection methods (Figure 6-13);
- Collection of ground water samples at 60 monitoring wells for VOCs and 30 wells for geochemical parameters for 30 or more years according to the following schedule:
 - Quarterly sampling during years 1 through 5,

- Semi-annual sampling during years 6 through 10, and
- Annual sampling during years 11 through 30; and
- Abandonment of the monitoring wells at the conclusion of the program.

6.4.5.2 *Common Remedial Alternative Components*

This remedial alternative also includes the three common components of Remedial Alternatives 2 through 6 described in Section 6.3. These components are the SMP for arsenic-impacted soil on the Hookston Station Parcel, vapor intrusion prevention systems at residences as necessary, and private well closures. The use of the A-Zone PRB reduces the required duration of the vapor intrusion prevention systems to 4 years.

6.4.6 *Remedial Alternative 6*

Remedial Alternative 6 utilizes ground water extraction with ex situ physical treatment and discharge to the local publicly-owned treatment works to address A- and B-Zone ground water. This combination of extraction and treatment technologies, commonly referred to as pump and treat, is designed to provide eventual treatment of VOCs in ground water and prevent further downgradient migration of impacted ground water. Figure 6-14 presents a conceptual cross-section view of the components of Remedial Alternative 6. Figure 6-15 presents a conceptual plan view of the proposed remedial systems.

Remedial Alternative 6 includes the following:

- Pumping water from A-Zone ground water extraction wells on both the Hookston Station Parcel and the downgradient study area and treatment prior to discharge to a publicly-owned treatment works;
- Pumping water from B-Zone ground water extraction wells on both the Hookston Station Parcel and the downgradient study area and treatment prior to discharge to a publicly-owned treatment works; and
- The three common remedial alternative components discussed in Section 6.3.

6.4.6.1 *A- and B-Zone Ground Water*

This remedial alternative involves the installation of ground water extraction wells placed within the A- and B-Zone Hookston Station TCE

plume. Extraction wells would be placed within the Hookston Station Parcel as well as the downgradient study area to capture ground water exceeding cleanup goals. Figure 6-15 presents a conceptual layout of the ground water extraction wells, as well as monitoring wells used to evaluate performance of the remedial action. The treatment provided by the A-Zone ground water extraction is expected to reduce concentrations of TCE to below the level at which indoor air impacts would be expected in a period of 2 years, allowing operation of the vapor intrusion prevention systems to cease after approximately 3 years. Ground water modeling performed to evaluate placement of extraction wells and operation duration determined that ground water extraction should be performed for 30 years or greater for A- and B-Zone ground water to achieve the MCL for TCE across the plume.

Implementation of this remedial action alternative for A- and B-Zone ground water would generally involve:

- Preparation of a remedial action work plan and obtaining appropriate permits;
- Installation of 20 A- and B-Zone ground water monitoring wells to evaluate performance of this remedial action (Figure 6-15);
- Installation of 15 A-Zone extraction wells, each constructed with 4-inch diameter casing and screen and including submersible pumps designed to operate at approximately 2 gallons per minute, based on recent aquifer tests conducted for the Hookston Station Parcel (Appendix G);
- Installation of five B-Zone extraction wells, each constructed with 6-inch diameter casing and screen and including submersible pumps designed to operate at approximately 50 gallons per minute, based on recent aquifer tests conducted for the Hookston Station Parcel (Appendix G);
- Installation of a tray air stripping system, including off-gas treatment by activated carbon, in the northeastern corner of the Hookston Station Parcel, designed to treat the total capacity of the A- and B-Zone ground water extraction wells described above;
- Subgrade piping of the extracted ground water to the above water treatment facility;
- Subgrade piping of the treated ground water to the nearest sanitary sewer connection;

- Subgrade conduit for electrical and instrumentation wiring of the well pumps to the above water treatment facility;
- Operation of the ground water extraction system for 30 or more years, including monthly water and air discharge sampling, monthly maintenance of treatment system equipment, and reporting;
- Collection of ground water samples at 60 monitoring wells for VOCs and 30 wells for geochemical parameters for 30 or more years according to the following schedule:
 - Quarterly sampling during years 1 through 5,
 - Semi-annual sampling during years 6 through 10, and
 - Annual sampling during years 11 through 30; and
- Abandonment of the treatment system, extraction wells, and monitoring wells upon achievement of ground water cleanup goals to the extent practicable or when treatment effectiveness has diminished to asymptotic levels.

6.4.6.2 *Common Remedial Alternative Components*

This remedial alternative also includes the three common components of Remedial Alternatives 2 through 6 described in Section 6.3. These components are the SMP for arsenic-impacted soil on the Hookston Station Parcel, vapor intrusion prevention systems at residences as necessary, and private well closures. The use of the A-Zone ground water extraction reduces the required duration of the vapor intrusion prevention systems to 3 years.

DETAILED COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES

Federal and California State statutory regulations require that remedial actions selected in the FS process must:

- Be protective of human health and the environment;
- Attain ARARs (or provide grounds for invoking a waiver);
- Be cost-effective;
- Utilize permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent possible; and
- Satisfy the preference for treatment that reduces TMV as a principal element or provide an explanation as to why it does not.

To demonstrate compliance with these requirements, this section provides a detailed and comparative analysis of the remedial alternatives developed in Section 6. The detailed analysis of each alternative involves:

- An evaluation of each remedial alternative with respect to the seven federal evaluation criteria described above; and
- An assessment of each remedial alternative with respect to its effectiveness in achieving RAOs.

The nine federal evaluation criteria as set forth in the NCP (40 CFR 300.430[e][9][iii]) are categorized into two threshold criteria, five balancing criteria, and two modifying criteria. The threshold criteria which must be met are:

- Overall protection of human health and the environment; and
- Compliance with ARARs.

Balancing criteria represent the primary criteria upon which the detailed and comparative analyses are based. The balancing criteria are:

- Long-term effectiveness and permanence;
- Reduction in TMV through treatment;
- Short-term effectiveness;

- Implementability; and
- Cost.

The modifying criteria, which will be evaluated by the RWQCB following review of the FS, are:

- State acceptance; and
- Community acceptance.

The components of the Remedial Alternatives, including costs, are summarized in Table 7-1. The detailed analysis for each alternative is presented in Section 7.2 and summarized in Tables 7-2 through 7-7. The comparative analysis is presented in Section 7.3 and summarized in Table 7-7. The development of detailed cost estimates for each of the alternatives is presented in Appendix J.

7.1 *DETAILED EVALUATION CRITERIA*

The nine federal evaluation criteria are described in the following subsections and are later used in the detailed alternatives analysis. The detailed and comparative analyses are based primarily on threshold and balancing criteria.

7.1.1 *Federal Evaluation Criteria*

7.1.1.1 *Overall Protection of Human Health and the Environment*

According to Federal FS guidance (USEPA 1988), overall protection of human health and the environment generally serves as a threshold determination, which must be met for an alternative to be eligible for selection as the preferred alternative. Thus, this criterion serves as a final “check” to assess whether each alternative provides adequate protection of human health, the environment, and the beneficial uses of ground water. It evaluates how risks posed by COCs are being eliminated, reduced, or controlled through treatment, engineering, or institutional controls. It also evaluates the degree to which the alternative satisfies RAOs.

7.1.1.2 *Compliance with Applicable, or Relevant and Appropriate Requirements*

This evaluation criterion is used to determine whether each alternative will meet ARARs, as presented in Section 4. Similar to protection of human health and the environment, this criterion generally serves as a

threshold determination which must be met for an alternative to be eligible for selection as the preferred alternative. Each alternative will be evaluated to determine compliance with chemical-, action-, and location-specific ARARs. Additionally, compliance with other applicable criteria, advisories, and guidelines (TBCs) will be considered.

7.1.1.3 *Long-Term Effectiveness and Permanence*

The long-term effectiveness and permanence criterion evaluates the long-term reliability of the proposed equipment and process and the permanence of the proposed alternative. This criterion evaluates the magnitude of residual risk posed by the presence of untreated waste or treatment residuals and the adequacy of institutional actions or containment measures needed to manage residual risk.

7.1.1.4 *Reduction of Toxicity, Mobility, or Volume through Treatment*

This criterion addresses the statutory preference for selecting remedial actions that employ treatment to permanently reduce TMV. It evaluates the degree to which the treatment is irreversible and the residual compounds that will remain following treatment. This criterion favors alternatives that utilize treatment to the maximum extent possible and generate little or no residual wastes.

7.1.1.5 *Short-Term Effectiveness*

The short-term effectiveness criterion measures the short-term risks to the community or remediation construction personnel that might occur during implementation of the remediation. This criterion also assesses the potential impact on the environment during remediation and the time required to meet remedial response objectives (e.g., cleanup goals).

7.1.1.6 *Implementability*

The implementability criterion evaluates technical and administrative feasibility of an alternative, and the availability of services and materials needed to implement the alternative. Evaluation of technical feasibility includes an assessment of the reliability of technologies and ease of undertaking additional remedial action, if necessary. This criterion favors proven technologies that are widely available and simple to implement or construct and operate.

7.1.1.7 *Cost*

The cost criterion assesses the financial burden associated with implementing the alternative. The factors that are addressed include capital costs, both direct and indirect, and O&M costs. Direct capital costs include construction costs or expenditures for labor, materials, equipment, and subcontractors associated with the remedial action. Indirect capital costs include expenditures for engineering, permitting, construction management, and other services necessary to carry out the remedial action. O&M costs include operational labor and maintenance materials associated with the extended O&M and reporting for each alternative. Costs are provided as net present value (NPV) costs. A discount rate of 7 percent is used for annual costs, which is the default discount rate recommended in the USEPA guidance, *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study* (USEPA 2000).

7.1.1.8 *State and Community Acceptance*

The State and community acceptance criteria are typically addressed together. The State acceptance criterion evaluates the technical and administrative issues and concerns that the State may have regarding each of the alternatives. The community acceptance criterion addresses the issues and concerns the public may have regarding each of the alternatives. These criteria are typically evaluated by the lead regulatory agency following regulatory and public review of the FS. Due to the uncertainty associated with these criteria at this stage, detailed evaluation of State and community acceptance is not included in this FS.

7.2 **DETAILED EVALUATION OF REMEDIAL ALTERNATIVES**

The detailed analyses of the remedial alternatives are presented in the following subsections. The components of each alternative, as well as the costs, are summarized in Table 7-1. Detailed cost estimates for each remedial alternative are presented in Appendix J. Tables 7-2 through 7-7 summarize the detailed analysis of each alternative. The evaluation balancing criteria long-term effectiveness, reduction of TMV, short-term effectiveness, and implementability were evaluated based on a numeric rating of 0 (no/none) to 5 (high) to quantify the degree to which the remedial alternative meets the criteria.

7.2.1 *Remedial Alternative 1 (No Action)*

The detailed analysis of Remedial Alternative 1 against the nine federal evaluation criteria is presented below and summarized in Table 7-2.

Overall Protection of Human Health and the Environment. As no actions would be taken to address RAOs, this alternative would provide no protection of human health and the environment (score = No).

Compliance with ARARs. This alternative would not meet ARARs identified for the Hookston Station because no remedial actions would be taken (score = No).

Long-Term Effectiveness and Permanence. The No Action alternative provides no effectiveness in the long term, as residual risks would be similar to, or greater than, baseline risks. No actions would be taken under this alternative, and therefore affected media would continue to pose a threat to human health and ground water quality. Therefore, this alternative has no long-term effectiveness (score = 0).

Reduction of TMV through Treatment. The No Action alternative does not involve treatment to address Hookston Station chemical constituents, and therefore this alternative does not provide any reduction in TMV. Therefore, this alternative has no reduction of TMV (score = 0).

Short-Term Effectiveness. This alternative is considered to have low - moderate short-term effectiveness. Although there would be no short-term risk to the community or workers related to implementation (because no actions are taken), the duration until cleanup goals would be met would be much greater than 30 years. Therefore, this alternative has low-moderate short-term effectiveness (score = 2).

Implementability. As no actions would be taken for this alternative, this alternative is highly implementable (score = 5).

Cost. No costs are associated with this alternative, as no remedial actions would be conducted. Because this alternative has no cost, it ranks highest compared with the other alternatives (score = 5).

State and Community Acceptance. The State and community acceptance criteria were not evaluated in this FS.

7.2.2

Remedial Alternative 2 (MNA and Common Components)

The detailed analysis of Remedial Alternative 2 against the nine federal evaluation criteria is presented below and summarized in Table 7-3.

Overall Protection of Human Health and the Environment. The remaining components of this alternative (i.e., vapor intrusion prevention and private well removal) would provide immediate protection of human health. However, as the time required to achieve the RAOs would be

significant, this alternative would not fulfill the criteria for protection of human health and environment (score = No).

Compliance with ARARs. While this alternative may eventually be able to reduce VOCs from the Hookston Station Parcel to below ARARs in certain areas, it is not expected to achieve ARARs in all areas. (score = No).

Long-Term Effectiveness and Permanence. MNA, when applied appropriately, can be both highly effective and permanent in the long term. However, in areas that are not conducive to biodegradation (e.g., where low organic carbon is present), intrinsic biodegradation may occur at very slow rates. Monitoring would ensure that geochemical conditions remain conducive to biodegradation throughout the attenuation period, and would be used to determine residual concentrations and/or the need to implement further treatment. Therefore, this alternative has low long-term effectiveness (score = 1).

Reduction of TMV through Treatment. The biodegradation component of MNA is capable of completely converting the TCE present on the Hookston Station Parcel into carbon dioxide, water, and chloride ions, although partial dechlorination may result in intermediate daughter compounds (i.e., vinyl chloride) that exhibit higher toxicity than the parent compound; therefore, care must be taken to ensure that conditions are appropriate for full dechlorination. Mobility reduction is achieved by two primary MNA mechanisms: through the destruction of COCs by biodegradation, and by physical adsorption into the aquifer matrix. Volume reduction is attained through destruction of contaminants through biodegradation.

As the primary receptor of VOC-impacted ground water from the Hookston Station Parcel is indoor air in the downgradient study area, significant reduction of toxicity is achieved through implementation of vapor intrusion prevention systems at residences with impacts, but the slow reduction of A-Zone VOCs in the downgradient study area may result in a temporarily expanded area of indoor air impacts. Therefore, this alternative has a low reduction of TMV (score = 1).

Short-Term Effectiveness. This alternative poses little risk to local receptors during implementation, and requires only the installation of new monitoring wells. However, the time required for this alternative to meet cleanup goals is lengthy and therefore this alternative has only moderate short-term effectiveness (score = 3).

Implementability. This alternative requires standard ground water sampling and analytical techniques, and therefore is considered readily implementable. The remaining components of this alternative (i.e., vapor intrusion prevention and private well removal) utilize readily available and easily implemented construction methods, but would require cooperation by residents to be effective. Therefore, this alternative has moderate-high implementability (score = 4).

Cost. The costs associated with this alternative are primarily long-term costs for ground water monitoring and sampling, expected to continue for 30 or more years under this alternative. In addition, costs associated with installation and maintenance of vapor intrusion prevention systems are included with this alternative, with maintenance expected to be required for approximately 30 years. The total estimated cost (NPV) of Remedial Alternative 2 is \$2,575,000. Of this total, \$314,010 is direct and indirect capital cost, \$2,261,000 is O&M cost (NPV). These costs are the lowest of the five alternatives with costs associated with remedial action (score = 4).

State and Community Acceptance. The State and community acceptance criteria were not evaluated in this FS.

7.2.3

Remedial Alternative 3 (A-Zone Bioremediation, B-Zone Chemical Oxidation, and Common Components)

The detailed analysis of Remedial Alternative 3 against the nine federal evaluation criteria is presented below and summarized in Table 7-4.

Overall Protection of Human Health and the Environment. Immediate risks due to VOCs in ground water would be addressed through vapor intrusion prevention systems and private well removal. Bioremediation of A-Zone ground water is expected to reduce VOC concentrations and prevent expansion of the ground water plume. However, given the discontinuous nature of the A-Zone, the effective distribution of biological amendments may prove to be difficult, which could result in additional work to ensure consistent and complete destruction of the contaminants.

The B-Zone chemical oxidation is capable of oxidizing chloroethenes into harmless byproducts with relatively high certainty. This alternative provides a moderate level of short- and long-term effectiveness and is expected to eventually meet risk-based RAOs. Therefore, this alternative is considered protective of human health and the environment (score = Yes).

Compliance with ARARs. Remedial Alternative 3 may be able to satisfy chemical-, action-, and location-specific ARARs. However, the ability of

this treatment method to destroy intermediate byproducts, such as cis-1,2-DCE and/or vinyl chloride, is less predictable. B-Zone VOCs are expected to be treated to chemical-specific ARARs through treatment by oxidation. This alternative is compliant with ARARs, recognizing that some uncertainty in the effectiveness of bioremediation exists (score = Yes).

Long-Term Effectiveness and Permanence. Nearly immediate and permanent reduction of the most highly concentrated VOCs in B-Zone ground water is expected with this alternative by chemical oxidation. This alternative is expected to result in limited residual contamination following completion and utilizes reliable technologies to achieve treatment.

The enhanced bioremediation can be implemented extensively across the portion of the A-Zone on the Hookston Station Parcel, but the accessibility of the downgradient study area is lower, resulting in a limited area of influence from the injected bioremediation amendment. This could produce a potential for localized areas of reduced treatment effectiveness and residual risk within the downgradient study area. Therefore, this alternative has moderate long-term effectiveness (score = 3).

Reduction of TMV through Treatment. Reduction of TMV of VOC-impacted ground water may be achieved through treatment by enhanced bioremediation (A-Zone) and chemical oxidation (B-Zone). Chemical oxidation of B-Zone TCE is expected to reliably reduce TMV in that water-bearing zone. The completeness of A-Zone bioremediation is uncertain, particularly within the downgradient study area, with the potential for localized untreated areas as well as temporary or permanent residual concentrations of vinyl chloride as a result of incomplete reductive dechlorination. The incomplete biodegradation may result in increased TMV, due to the increased mobility and toxicity of vinyl chloride, relative to its parent compound, TCE. Therefore, this alternative has low-moderate reduction of TMV (score = 2).

Short-Term Effectiveness. This alternative presents minimal risk to the community because the technology with the greatest risk associated with implementation, chemical oxidation, is limited to ground water on the Hookston Station Parcel. Workers performing the chemical oxidation injections would be in contact with potassium permanganate, which is an oxidizer that requires special handling. However, worker exposure can be minimized by the use of appropriate health and safety protocols and personal protective equipment (PPE). The technology used for A-Zone ground water, in situ bioremediation, utilizes harmless food-grade materials for enhancement that do not pose an immediate threat to workers or the community. Immediate contaminant risks would be

reduced through vapor intrusion prevention systems and removal of private supply wells. However, the expected long duration of bioremediation within the downgradient study area, due to the limited area over which this can be implemented within the footprint of the downgradient study area, results in reduced short-term effectiveness. Therefore, this alternative has moderate short-term effectiveness (score = 3).

Implementability. Materials and services needed for remedial action are readily available, and technologies are reliable and proven, with the exception of enhanced bioremediation for which reliability must be proven on a site-specific basis. Installation of monitoring wells and bioremediation injection wells and periodic injection of a bioremediation amendment within the downgradient study area would require coordination with city agencies. Installation of vapor intrusion prevention systems and decommissioning of private wells would require cooperation with residents. Therefore, this alternative has a moderate level of implementability (score = 3).

Cost. The cost associated with this alternative includes design of the injection systems, chemical injection, and long-term ground water monitoring. In addition, costs associated with installation and maintenance of vapor intrusion prevention systems are included with this alternative, with maintenance expected to be required for approximately 6 years. The total estimated cost (NPV) of Remedial Alternative 3 is \$4,930,000. Of this total, \$3,014,000 is direct and indirect capital cost, \$1,916,000 is O&M cost (NPV). These are mid-range costs compared with the other alternatives (score = 3).

State and Community Acceptance. The State and community acceptance criteria were not evaluated in this FS.

7.2.4

Remedial Alternative 4 (A-Zone PRB, B-Zone Chemical Oxidation, and Common Components)

The detailed analysis of Remedial Alternative 4 against the nine federal evaluation criteria is presented below and summarized in Table 7-5.

Overall Protection of Human Health and the Environment. Immediate risks due to VOCs in ground water would be addressed through vapor intrusion prevention systems and private well removal. Placement of a zero-valent iron PRB would be expected to quickly reduce VOC concentrations under residences to concentrations below levels that will prevent unacceptable indoor air impacts. Zero-valent iron has been shown to successfully treat chlorinated ethenes such as TCE. Future

protection of B-Zone ground water would be accomplished through treatment using chemical oxidation, as in Remedial Alternative 3. This alternative provides a high level of short- and long-term effectiveness and is expected to meet risk-based RAOs and therefore is considered protective of human health and the environment (score = Yes).

Compliance with ARARs. This alternative is expected to be able to satisfy chemical-, action-, and location-specific ARARs. A-Zone ground water is expected to reach ARARs within a reasonable time frame, particularly the 530 µg/L ground water screening level for protection of residential indoor air. A-Zone ground water would take longer to reach the ARAR of the MCL for ground water. B-Zone VOCs are expected to be treated to chemical-specific ARARs through treatment by oxidation. Therefore, this alternative is compliant with ARARs (score = Yes).

Long-Term Effectiveness and Permanence. This alternative would be effective in the long term for A-Zone ground water by providing immediate and permanent destruction of VOCs as ground water flows through the PRB. Nearly immediate and permanent reduction of the most highly concentrated VOCs in B-Zone ground water is expected with this alternative by chemical oxidation. This alternative is expected to result in limited residual contamination following completion and utilizes reliable technologies to achieve treatment. Therefore, this alternative has a high level of long-term effectiveness (score = 5).

Reduction of TMV through Treatment. Significant reduction of TMV of VOC-impacted ground water is expected within the area and water-bearing zone with the greatest risk to receptors, A-Zone ground water below residential properties. The PRB is expected to immediately reduce the toxicity of A-Zone ground water as it passes through the PRB. Treatment of B-Zone ground water by chemical oxidation would reduce TMV across the plume extent. Therefore, this alternative has moderate-high reduction of TMV (score = 4).

Short-Term Effectiveness. Trenching or injection performed to place zero-valent iron PRB would pose a predictable risk to construction workers, although this construction method is well established. Construction controls would be required to reduce risk to community members. Workers performing the chemical oxidation injections would be in contact with potassium permanganate, which is an oxidizer that requires special handling. However, worker exposure can be minimized by the use of appropriate health and safety protocols and PPE. Immediate contaminant risks would be reduced through vapor intrusion prevention systems and removal of private supply wells. The expected time frame to achieve treatment to the level at which indoor air risks are reduced is expected to

be short, while achieving the ultimate cleanup goal of the MCL for ground water would take longer, without posing immediate risks. The limited risks to community during implementation and the long duration of some components of this alternative results in a moderate-high short-term effectiveness (score = 4).

Implementability. Materials and services needed for remedial action are readily available, and technologies are reliable and proven. Installation of the PRB would require significant construction and proper coordination with residences and city agencies. This would be true of either a trenched or injected PRB, with the trenched PRB presenting greater installation difficulties, due to potential presence of subsurface utilities. Installation of vapor intrusion prevention systems and decommissioning of private wells would require cooperation with residents. Therefore, this alternative has a moderate level of implementability (score = 3).

Cost. The cost associated with this alternative includes performing a reaction column test, performing hydrogeologic testing, designing the iron PRB, trenching and installing the PRB, and long-term ground water monitoring. In addition, chemical injection would be performed on the Hookston Station Parcel and costs associated with installation and maintenance of vapor intrusion prevention systems are included with this alternative, with maintenance expected to be required for approximately 4 years. The total estimated cost (NPV) of Remedial Alternative 4 is \$5,194,000. Of this total, \$3,214,000 is direct and indirect capital cost, \$1,980,000 is O&M cost (NPV). These are mid-range costs compared with the other alternatives (score = 3).

State and Community Acceptance. The State and community acceptance criteria were not evaluated in this FS.

7.2.5 *Remedial Alternative 5 (A-Zone and B-Zone PRB and Common Components)*

The detailed analysis of Remedial Alternative 5 against the nine federal evaluation criteria is presented below and summarized in Table 7-6.

Overall Protection of Human Health and the Environment. This alternative is identical to Remedial Alternative 4 with addition of a PRB to treat B-Zone ground water similar to the PRB specified for A-Zone ground water in Remedial Alternative 4. Immediate risks due to VOCs in ground water are addressed through vapor intrusion prevention systems and private well removal. Placement of a zero-valent iron PRB is expected to quickly reduce VOC concentrations in A-Zone ground water under residences to concentrations below levels that will prevent further indoor

air impacts. The B-Zone PRB is expected to prevent further migration of VOCs in the downgradient study area. This alternative provides a moderately high level of short- and long-term effectiveness and is expected to meet risk-based RAOs and therefore is considered protective of human health and the environment (score = Yes).

Compliance with ARARs. This alternative is expected to satisfy chemical-, action-, and location-specific ARARs in the downgradient study area within a reasonable time frame, as ground water is treated as it passes through the A- and B-Zone PRBs. Ground water would take longer to reach the ARAR of the MCL for ground water. Therefore, this alternative is compliant with ARARs (score = Yes).

Long-Term Effectiveness and Permanence. This alternative would be effective in the long term for A- and B-Zone ground water by providing immediate and permanent destruction of VOCs as ground water flows through the PRB. This alternative utilizes reliable technologies to achieve treatment where the primary risk pathways are present, but may have the potential for residual contamination (B-Zone within the Hookston Station Parcel) following completion. Therefore, this alternative has a moderate - high level of long-term effectiveness (score = 4).

Reduction of TMV through Treatment. Significant reduction of TMV of VOC-impacted ground water is expected within the area and water-bearing zone with the greatest risk to receptors, A-Zone ground water below the residential property. The PRB is expected to immediately reduce the toxicity of ground water. The TMV of ground water within the Hookston Station Parcel is expected to eventually reduce as a result of natural degradation processes, but this is expected to take a significant amount of time. Therefore, this alternative has moderate reduction of TMV (score = 3).

Short-Term Effectiveness. This alternative is expected to use an injection method to place a zero-valent iron PRB. This construction would pose a predictable risk to construction workers and potentially community members. Construction controls would be required to reduce risk to community members. The expected time frame to achieve treatment to the level at which indoor air risks are reduced is expected to be short, while achieving the ultimate cleanup goal of the MCL for ground water would take significantly longer without posing immediate risks.

The limited risks to community during implementation and the long duration of some components of this alternative results in a moderate-high short-term effectiveness (score = 4).

Implementability. Materials and services needed for remedial action are readily available, and technologies are reliable and proven. Installation of the PRB would require significant construction and proper coordination with residences and city agencies. The deeper A- and B-Zone placement of the PRB would require a greater time frame and the use of innovative injected PRB methods. Installation of vapor intrusion prevention systems and decommissioning of private wells would require cooperation with residents. Therefore, this alternative has a moderate level of implementability (score = 3).

Cost. The cost associated with this alternative includes performing a reaction column test, performing hydrogeologic testing, designing the iron PRB, trenching and installing the PRB, and long-term ground water monitoring. In addition, maintenance of vapor intrusion prevention systems are included with this alternative, with maintenance expected to be required for approximately 4 years. The total estimated cost (NPV) of Remedial Alternative 5 is \$8,739,000. Of this total, \$7,068,000 is direct and indirect capital cost, \$1,671,000 is O&M cost (NPV). These are medium to high range costs compared with the other alternatives (score = 2).

State and Community Acceptance. The State and community acceptance criteria were not evaluated in this FS.

7.2.6 *Remedial Alternative 6 (Ground Water Extraction, Treatment, and Disposal, and Common Components)*

The detailed analysis of Remedial Alternative 6 against the nine federal evaluation criteria is presented below and summarized in Table 7-7.

Overall Protection of Human Health and the Environment. Immediate risks due to VOCs in ground water addressed through vapor intrusion prevention systems and private well removal. Ground water extraction and treatment across A- and B-Zone plumes would prevent further migration of VOCs. Ground water extraction is expected to quickly reduce TCE concentrations in A-Zone ground water to below the 530 µg/L screening level for residential indoor air impacts. However, achievement of MCLs across the A- and B-Zone plume extent is expected require long-term operation of the active pump and treat system. This alternative provides a moderately high level of short- and long-term effectiveness and is expected to meet risk-based RAOs and therefore is considered protective of human health and the environment (score = Yes).

Compliance with ARARs. This alternative is expected to satisfy chemical-specific ARARs for ground water (score = Yes).

Long-Term Effectiveness and Permanence. Plume-wide ground water extraction is expected to provide effective and relatively fast reduction of A-Zone TCE to concentrations reducing associated risks associated with migration to indoor air. However, this alternative relies on long-term O&M of an extraction and treatment system to achieve MCLs in A- and B-Zone ground water. Therefore, this alternative has a moderate-high level of long-term effectiveness (score = 4).

Reduction of TMV through Treatment. Reduction of TMV is expected with this alternative, through extraction of TCE-impacted ground water. However, the contaminants are simply removed from ground water, rather than being destroyed in situ. Contaminants would be transferred between media at several stages of the treatment process. In addition, the highly stratified soils in the A-Zone may limit the effective hydraulic capture zones, resulting in localized untreated zones and higher residual TMV. Pumping may also significantly alter the local hydraulic gradients, which could result in the migration of chemicals from other (non-Hookston) sources into the neighborhood. Therefore, this alternative has moderate reduction of TMV (score = 3).

Short-Term Effectiveness. This alternative would require significant infrastructure associated with the treatment. Numerous extraction wells would be constructed within the downgradient study area, resulting in potential impacts to residents. However, construction methods are standard, with easily mitigated effects. The long duration of system O&M for this alternative reduces the level of short-term effectiveness. The expected time frame to achieve treatment to the level at which indoor air risks are reduced is expected to be short, while achieving the ultimate cleanup goal of the MCL for ground water would take significantly longer without posing immediate risks. The limited risks to community during implementation and the long duration of some components of this alternative results in a moderate-high short-term effectiveness (score = 4).

Implementability. This alternative requires construction, operation, and maintenance of significant infrastructure to implement plume-wide ground water extraction and treatment. Most of the construction would be within the community in the downgradient study area and would be relatively intrusive, considering the number of wells and extent of trenching required for conveyance piping and wiring. However, the construction methods and equipment are readily available and implementable. Installation of vapor intrusion prevention systems and decommissioning of private wells would require cooperation with residents. Therefore, this alternative has a low to moderate level of implementability (score = 2).

Cost. The cost associated with this alternative includes installation of 15 A-Zone and five B-Zone ground water extraction wells, installation of conveyance piping from the wells to a treatment center located on the Hookston Station Parcel, and construction of the treatment system consisting of an air stripper with activated carbon off-gas treatment and associated equipment. The extraction and treatment system would be operated for at least 30 years, including performance of long-term ground water monitoring. In addition, costs associated with installation and maintenance of vapor intrusion prevention systems is included with this alternative, with maintenance expected to be required for approximately 3 years. The total estimated cost (NPV) of Remedial Alternative 6 is \$12,807,000. Of this total, \$1,900,000 is direct and indirect capital cost, \$10,906,000 is O&M cost (NPV). These costs are high compared with the other alternatives (score = 1).

State and Community Acceptance. The State and community acceptance criteria were not evaluated in this FS.

7.3 *COMPARATIVE ANALYSIS*

In this section, the six alternatives evaluated in the sections above are evaluated relative to one another for each evaluation criteria. The comparative analysis identifies the relative advantages and disadvantages of each alternative. Table 7-8 summarizes the results of the comparative analysis.

7.3.1 *Overall Protection of Human Health and the Environment*

The overall protection of human health and the environment criterion serves as a final check to ensure that each alternative provides adequate protection of human health and the environment. This criterion draws on the assessment of other evaluation criteria to determine if this protection is achieved and serves as a final check for overall acceptability of the alternative. During the comparative analysis of alternatives, overall protection of human health and the environment serves as a threshold criterion that must be met for eligibility of selection (USEPA 1988).

As described in Section 7.2, two of the six alternatives evaluated during this FS did not meet the threshold of overall protection of human health and the environment, Remedial Alternatives 1 and 2. These alternatives have low levels of long-term effectiveness and reduction of TMV, and therefore are not protective of human health and the environment. Remedial Alternatives 3 through 6 were all determined to be protective of

human health and the environment, and would be acceptable for selection.

7.3.2 *Compliance with ARARs*

Similar to overall protection of human health and the environment, the compliance with ARARs criterion serves as a final check based on overall performance of the alternatives. This criterion is used to ensure that each alternative is expected to meet ARARs following implementation. During the comparative analysis of alternatives, compliance with ARARs serves as a threshold criterion that must be met for eligibility of selection (USEPA 1988).

For ground water, the primary ARAR for which the alternatives and associated technologies were designed to meet is the 530 µg/L TCE screening level for protection of residential indoor air in the downgradient study area. The secondary ARAR considered is the MCL for TCE and associated VOCs. Remedial Alternatives 1 and 2 are not expected to meet these ARARs within a reasonable time frame. Remedial Alternatives 3 through 6 are expected to take varying but similar durations to achieve respective ARARs.

7.3.3 *Long-Term Effectiveness and Permanence*

Remedial Alternative 4 provides the highest level of long-term effectiveness and permanence because this alternative utilizes a proven treatment technology to completely and permanently destroy TCE in A-Zone ground water migrating toward residences within the downgradient study area. In addition, this alternative incorporates an aggressive treatment of VOCs in B-Zone ground water designed to permanently destroy contaminants and reduce the potential for further migration in that water-bearing zone. This alternative would result in the lowest residual risk because of the ability of the technology to completely destroy contaminants and achieve low cleanup concentrations.

Remedial Alternative 5 provides a slightly lower level of long-term effectiveness and permanence than Remedial Alternative 4 due to the lack of treatment of B-Zone ground water on the Hookston Station Parcel.

Remedial Alternative 6 provides a similar level of long-term effectiveness and permanence as Remedial Alternative 5 due to the lack of B-Zone ground water source zone treatment. Pump and treat does offer reduced risk associated with the need for replacement, due to the adaptability of pump and treat. Although the pump and treatment associated with this alternative provides a slightly faster reduction in A-Zone ground water

concentrations than a PRB, the ability for pump and treat to achieve low cleanup values is not proven. The residual risk posed by these higher remaining concentrations offsets the benefit derived from the adaptability.

If completely successful, Remedial Alternative 3 has the potential to result in a high long-term effectiveness and permanence, as it combines in situ treatment in the A-Zone on both the Hookston Station Parcel and downgradient study area with in-situ treatment in the B-Zone on the Hookston Station Parcel. When effective, enhanced anaerobic bioremediation is capable of treating to very low concentrations, thus lowering the residual risk. However, it is uncertain whether the biological amendments can be sufficiently distributed throughout the A-Zone, or whether enhanced bioremediation would be able to achieve permanent and complete destruction of TCE without the final production of 1,2-DCE and/or vinyl chloride. In addition, the areas where implementation of bioremediation is possible within the downgradient study area is limited, resulting in areas with limited treatment. These uncertainties increase the potential that this alternative would need to be altered at a later date to increase the distribution of the biological amendments or to provide additional treatment of residual 1,2-DCE and/or vinyl chloride that may pose a residual risk to residential indoor air. Therefore, this alternative has the lowest long-term effectiveness of all the “active remediation” alternatives.

Remedial Alternative 2 provides some level of long-term effectiveness by implementing vapor intrusion prevention at residences within the downgradient study area with known indoor air impacts from VOCs in ground water from the Hookston Station Parcel. However, with the lack of treatment beyond the natural mechanisms used in MNA and the uncertainty of complete degradation, Remedial Alternative 2 has a lower long-term effectiveness.

Based on this analysis, Remedial Alternative 4 ranks highest (score of 5) for long-term effectiveness, with Remedial Alternatives 5 and 6 (score of 4) ranking just below Remedial Alternative 4. Remedial Alternatives 3 (score = 3), 2 (score = 1), and 1 (score = 0) rank progressively lower for long-term effectiveness and permanence.

7.3.4 *Reduction of Toxicity, Mobility, or Volume through Treatment*

Remedial Alternatives 3 through 6 are expected to reduce TMV of TCE-impacted ground water from the Hookston Station Parcel through active remediation. All of these alternatives rely upon technologies that permanently destroy or remove contaminants in ground water, and therefore are not “reversible” processes.

Remedial Alternative 4 is expected to most reliably reduce TMV through in situ treatment by the A-Zone PRB and B-Zone chemical oxidation. Remedial Alternative 3 may be capable of achieving similar reduction of TMV through in situ anaerobic bioremediation of A-Zone ground water, but the uncertainty of complete destruction of TCE by this method results in a lower ranking for this alternative.

Remedial Alternative 5 would similarly treat A-Zone ground water as Remedial Alternative 4. However, Remedial Alternative 4 addresses the higher concentrations within the B-Zone more directly, and therefore carries a higher ranking for this evaluation criterion than Remedial Alternative 5. Remedial Alternative 6 is also expected to reduce TMV of TCE-impacted ground water, but only through phase-transfer processes, rather than in situ destruction. The low conductivity of the A-Zone is expected to decrease the ability of the A-Zone pump and treat component of Remedial Alternative 6 to reduce volume of low-concentration ground water as much as other in situ technologies. Chemicals from other (non-Hookston) sources could also be mobilized by this system due to the increased hydraulic gradients that would be created. Therefore, this alternative carries a lower ranking than the technologies with active, proven remedial technologies.

Remedial Alternative 2 is expected to reduce TMV through contaminant destruction (biodegradation) and reduction in mobility (adsorption). However, MNA may result in a temporary expansion of the ground water plume before natural degradation processes can begin reducing TMV, especially in the B-Zone where greater concentrations of VOCs are present. As a result, this alternative ranks lower than all active remediation alternatives.

Based on this analysis, Remedial Alternative 4 ranks highest (score of 4) for reduction of TMV. Remedial Alternatives 5 and 6 (score of 3) rank below Remedial Alternative 4, followed by Remedial Alternatives 3 (score of 2), 2 (score of 1), and 1 (score of 0) for achievement of reduced TMV.

7.3.5 *Short-Term Effectiveness*

As described in Section 7.1.1.5, the comparative analysis using the short-term effectiveness criterion focuses on two separate factors: 1) which technologies have the lowest risk to residents and construction workers *during implementation*, and 2) which alternatives can most rapidly achieve cleanup goals. For purposes of this comparative analysis, each of these two factors have been considered separately and the results merged into a single scoring and ranking for the alternatives. Treatment duration has been weighted slightly higher in this evaluation due to the reliance upon

the selected alternative to be protective of human health, and the ability to effectively mitigate construction and implementation risks.

All five alternatives that incorporate the vapor intrusion prevention systems and private well removal (i.e., Remedial Alternatives 2 through 6) have a similar immediate reduction of the primary risks associated with TCE in ground water. With respect to treatment duration, two endpoints have been considered: 1) the time until MCLs are met, and 2) the time until vapor intrusion should no longer present an unacceptable risk. Of the five treatment alternatives, Remedial Alternative 2 has the longest treatment time until MCLs would be met. Therefore, this alternative ranks the lowest (with the exception of No Action) in this respect. The remaining treatment alternatives (Remedial Alternatives 3 through 6) all require 30 or more years to meet MCLs and therefore all score similarly based on this factor.

With regard to the time required to reduce ground water concentrations such that no unacceptable risk is posed to residents in the downgradient study area, the treatment durations provided in Table 7-1 are referenced. Of the treatment alternatives, Remedial Alternative 2 has the longest treatment duration. Remedial Alternative 6 has the shortest duration, with Remedial Alternatives 4 and 5 both requiring slightly longer. Of the active remediation alternatives, Remedial Alternative 3 has the longest duration until indoor air is no longer expected to present an unacceptable risk based on ground water concentrations.

Regarding implementation risk to residents and construction workers, Remedial Alternatives 1 and 2 present the lowest risk as little to no construction is required. Remedial Alternative 3 has slightly more implementation risk due to the use of drilling and injecting equipment, and the handling of oxidizing chemicals (i.e., potassium permanganate) as part of the remedy. Similarly, Remedial Alternative 6 carries some implementation risk due to the installation of large amounts of equipment and piping in a residential area. Remedial Alternatives 4 and 5 carry the highest implementation risk due to installation of the PRB and the associated construction risks. Although the PRB in Remedial Alternative 4 is only designated for the A-Zone and therefore has less risk associated with the PRB installation component, this alternative also involves handling of oxidants, and thus the benefit is off-set.

Based on this analysis, and combining consideration of the two primary elements of short-term effectiveness (i.e., implementation risk and treatment duration), Remedial Alternatives 4, 5, and 6 rank highest (score of 4), followed by Remedial Alternatives 2 and 3 (score of 3), and Remedial Alternative 1 (score of 2) for short-term effectiveness.

7.3.6 *Implementability*

Remedial Alternatives 1 and 2 are considered highly implementable. Remedial Alternative 1 requires no action and is therefore by definition highly implementable. Remedial Alternative 2 involves long-term monitoring of ground water, as well as implementation of vapor intrusion prevention components and private well removal. The need to access private residences for these components slightly lessens the implementability of the alternative.

Remedial Alternatives 3 through 6 also utilize, in addition to vapor intrusion prevention components and private well removal, the addition of remedial technologies that present technical and administrative hurdles. Each of these alternatives possess similar administrative and technical feasibility associated with the permitting, implementation, and construction of the remedial components. All of the alternatives require access to private land, including residences, and involve the injection or extraction of materials into or from the subsurface. Remedial Alternative 6 is slightly less implementable because it is a long-term active system that would require the largest infrastructure development and high maintenance.

Based on this analysis, Remedial Alternative 1 ranks highest (score of 5) followed by Remedial Alternative 2 (score of 2), Remedial Alternatives 3, 4, and 5 (score of 3), and Remedial Alternative 6 (score of 2) for implementability.

7.3.7 *Cost*

Remedial Alternative 6 is the most costly alternative at \$12,807,000. Remedial Alternative 2 is the least costly of the active alternatives at \$2,575,000. No cost is associated with Remedial Alternative 1. Remedial Alternatives 3, 4, and 5 have progressively greater costs of \$4,930,000, \$5,194,000, and \$8,739,000, respectively.

7.3.8 *State and Community Acceptance*

The State and community acceptance criteria were not evaluated in this FS.

7.4 *PREFERRED REMEDIAL ALTERNATIVE*

The purpose of the detailed and comparative analysis presented in Sections 7.2 and 7.3 is to provide a basis for determining which remedial

alternative is most appropriate for protecting human health and the environment and managing long-term risk. This section summarizes the results of the detailed and comparative analysis in Section 7, and recommends a preferred alternative based on the comparative analysis. The final selection of a preferred alternative will be made following agency and public response. Table 7-8 summarizes the results of the comparative analysis.

Remedial Alternative 4 is the preferred remedial alternative. As shown in Table 7-8, and described in Section 7.3, Remedial Alternative 4 consistently ranks higher or as high as the other alternatives evaluated in this FS for every evaluation criteria. In addition, this alternative has a total cost that falls at a mid-point between the other active alternatives. Remedial Alternative 4 satisfies the threshold criteria of protectiveness and compliance with ARARs. This alternative is moderately to highly effective at satisfying all balancing and modifying criteria (long-term effectiveness and permanence, reduction of TMV through treatment, short-term effectiveness, implementability, and State and community acceptance).

The components of Remedial Alternative 4 are more completely described in Section 8.0.

This section provides an initial Implementation Plan that describes the work components and preliminary procedures that would be necessary to implement the preferred remedial alternative for the Hookston Station Parcel. Remedial Alternative 4, as described above in Sections 6 and 7, utilizes a combination of institutional controls, engineering controls, and in situ ground water treatment to achieve RAOs.

This Implementation Plan constitutes an initial conceptual design, and due to the preliminary nature, is subject to change, based on agency review and public comments on the FS. In addition, components of work described herein for Remedial Alternative 4 may be refined following completion of treatability studies, field pilot tests, and more intensive Remedial Design.

The selected preferred alternative (Remedial Alternative 4), includes the following components:

- Zero-valent iron PRB for A-Zone ground water;
- Chemical oxidation for B-Zone ground water;
- Institutional controls for arsenic-impacted subsurface soil in the form of an SMP;
- Vapor intrusion prevention systems; and
- Removal of private wells, which have been used for irrigation and filling swimming pools, from residences that overlie the downgradient study area.

This section is divided into five primary sections:

- Section 8.1 describes the field investigations necessary to complete a full-scale design of the remediation systems;
- Section 8.2 describes work plans and permits that may be necessary;
- Section 8.3 describes the general scope of the remedial action implementation;
- Section 8.4 describes the effectiveness monitoring program; and
- Section 8.5 provides an approximate implementation schedule.

8.1 *PRE-DESIGN INVESTIGATIONS*

Prior to development of a full-scale design for the selected remedial action, additional investigation activities would be performed to refine design parameters for implementation. Several investigation tasks, described below, would be performed supporting implementation of the zero-valent iron PRB, chemical oxidation, and vapor intrusion prevention.

8.1.1 *Monitoring Well Installation and Baseline Sampling*

Several additional monitoring wells would be installed to provide a more complete ground water monitoring network for evaluating the performance of the remedial action components. Installation and sampling of these wells prior to final design of the remedial action components would allow more accurate design of the scale of the remedial action.

As part of this task, several new monitoring wells within the A- and B-Zones would be installed. These wells would be installed prior to completion of the final design of the A-Zone PRB and B-Zone chemical oxidation. The wells would be installed using the standard operating procedures developed for the Hookston Station Parcel (ERM 2000). Monitoring wells would be placed to maximize their value as performance monitoring points for the PRB (i.e., spaced at various distances up- and downgradient of the barrier's planned location).

Following installation of the wells described above, a complete ground water sampling event would be performed to provide baseline conditions of VOC concentrations. Ground water would be sampled from monitoring wells within the study area. Samples from all monitoring wells sampled would be analyzed for VOCs. Samples from a subset of the wells sampled would be analyzed for geochemical parameters, including:

- Dissolved gases (methane, ethane, ethene, hydrogen);
- Dissolved and total metals (iron and manganese);
- Ions (chloride, sulfate, nitrate);
- Total organic carbon; and
- Alkalinity.

Physical parameters, such as temperature, acidity/alkalinity (pH), dissolved oxygen, and oxidation-reduction potential, would also be collected during the well sampling program.

8.1.2 *Direct-Push Sampling*

In addition to the monitoring well program described above, a ground water investigation would be completed along the proposed length of the PRB. In order to further delineate the subsurface geology and distribution of VOCs, an in-situ, real-time investigation tool (e.g., cone penetrometer testing [CPT] rig equipped with a membrane interface probe [MIP] or a Waterloo Profiler™ device) would be utilized. It is anticipated that a CPT/MIP or Waterloo Profiler™ sampling location would be completed approximately every 50 feet along the proposed length of the PRB (Figure 6-10). Borings would be completed to a depth of approximately 70 feet (just below the bottom of the B-Zone aquifer). The objective of this pre-design study is to optimize the placement (depth and length) of the PRB for maximum benefit.

A similar sampling program would be completed in the vicinity of MW-11B, located on the western property line behind the commercial building at 199 Mayhew Way. MW-11B contains considerably higher concentrations of TCE than the co-located A-Zone well, MW-11A. Previously, five HydroPunch borings (B-101 through B-105) were completed at locations upgradient of MW-11B in attempt to locate a potential upgradient source for this contamination. No TCE was found during that investigation. Additional sampling is proposed to verify these previous HydroPunch data and to support the Remedial Design. Four borings (either CPT/MIP or Waterloo Profiler™) would be completed along the western property boundary and at locations in the downgradient study area near MW-11B (Figures 6-10 and 6-11). Borings would be completed to a depth of approximately 70 feet (just below the bottom of the B-Zone aquifer). This pre-design investigation is intended to better determine the optimal locations for the B-Zone chemical oxidation injections.

A work plan outlining the scope of work and sampling procedures would be developed, and would be submitted to the RWQCB for approval prior to implementing the investigation activities.

8.1.3 *PRB Bench-Scale Testing*

Prior to completing the detailed Remedial Design for the zero-valent iron PRB, bench testing must be completed to obtain data to determine design parameters. Data from the bench testing would be used to specify the quantity and grain-size of iron material to use in the PRB, the required residence time, the dimensions of the barrier, and the expected effectiveness of the reduction.

Bench testing would be performed in a column, simulating the conditions of the PRB. A-Zone ground water would be collected from monitoring wells in the vicinity of the proposed PRB and would be used in the bench test. Ground water would be pumped through the column at a rate simulating the A-Zone ground water flow velocity.

Following startup of the column test, effluent samples would be collected at discrete locations within the column at specific periods following startup. Samples would be analyzed for the COCs, TCE and daughter products, as well as for other parameters indicative of performance of the PRB, such as cations (iron, sodium, manganese, calcium, potassium, etc.), anions (nitrate, chloride and sulfate), alkalinity, and standard water quality parameters (pH, oxidation-reduction potential, conductivity, etc.).

The column test would be performed over several weeks. Based on the results of the column test, a more accurate estimate of the scale and cost of the PRB would be possible. This would allow the PRB construction specifications to be finalized for design and contracting purposes.

8.1.4 *Chemical Oxidation Pilot Testing*

Bench-scale treatability testing was previously performed to determine the potential effectiveness of chemical oxidation at Hookston Station (Appendix C). The bench testing indicated that chemical oxidation using potassium permanganate solution could be cost-effectively applied to B-Zone ground water due to a low soil oxidant demand. This bench test also resulted in an approximate value for soil oxidant demand of 1.9 pound of potassium permanganate per cubic yard within the B-Zone.

Prior to full-scale implementation, an in-field pilot study would be performed to support the final Remedial Design (i.e., determine optimal injection rates, well spacing, etc.) and verify the effectiveness of this chemical treatment within the aquifer. The pilot study would consist of a small network of direct-push injections of potassium permanganate near the upgradient boundary of the B-Zone TCE plume. The pilot study would strive to test the effectiveness of chemical oxidation in the area of the plume with the highest TCE concentrations. Temporary monitoring wells would be installed at varying distances downgradient of the injection points. Monitoring of ground water conditions prior to and following the injection would be used to evaluate the effectiveness of the technology and refine design parameters to be incorporated into the Remedial Design. A work plan outlining the scope of work and sampling procedures would be developed prior to implementation for review and approval by the RWQCB.

8.2 *REMEDIAL DESIGN, DOCUMENTATION, AND PERMITTING*

Several phases of documentation would be required prior to implementation of the components of Remedial Alternative 4. The expected documentation phases are described below.

8.2.1 *Pre-Design Investigation Work Plan*

This work plan would provide specifications for the investigation phases described above in Section 8.1. This document would include provisions for permitting monitoring well installation with the Contra Costa County Environmental Health Division.

8.2.2 *Remedial Design*

Following completion of the pre-design investigation phases, a Remedial Design would be developed that documents the detailed construction specifications for implementation of the components of Remedial Alternative 4. These components include the A-Zone PRB, the B-Zone chemical oxidation, as well as the vapor intrusion prevention systems and private well removal. The Remedial Design would be conducted in phases to allow an initial design to be used to work with PRB contractors to select the most appropriate installation method and incorporate components specific to that method into final designs. This design would provide details for the permitting process for all of the construction components.

8.2.3 *Soil Management Plan*

As described in Section 7, arsenic in soils does not currently present an unacceptable risk to commercial/industrial workers. Impacted soils would remain in place under this alternative, and potential future exposures to the single location of elevated arsenic in subsurface soils by construction workers would be addressed through an SMP. This document is the primary component of the institutional controls used to protect construction workers from arsenic-impacted shallow soil at the Hookston Station Parcel. The SMP would be developed in cooperation with all current Hookston Station property owners. The SMP would provide standard operating procedures for all subsurface construction performed on the Hookston Station Parcel, including construction of subsurface utilities and larger-scale excavation work. The SMP would also provide procedures for handling and disposal of soil excavated during construction activities.

This section describes the implementation of the remedial action components of Remedial Alternative 4. This discussion is intended to provide a preliminary description of how the specific components of this alternative would be implemented.

8.3.1***A-Zone Zero-Valent Iron PRB***

Based on the results of the PRB bench testing and baseline ground water sampling described in Section 8.1, and a survey of the proposed location of the PRB, the installation methods for the PRB would be evaluated. Due to the relatively shallow depth of the A-Zone, multiple installation methods are available with varying benefits. This section provides only a general description of installation of the PRB, as the installation method has not yet been determined. The general location of the A-Zone PRB is presented on Figure 6-10. This location may be refined based on the results of the baseline ground water sampling described in Section 8.1.

The two primary installation methods being considered for the PRB are trenching and direct injection. Placement of zero-valent iron in a PRB has been commonly performed by trenching in areas where a continuously-excavated trench is possible. The trenching can be performed using several methods, including standard backhoe trenching for shallow trenches, clamshell excavation for very deep trenches, and excavation with a continuous trencher for fast trench installation. In addition, several innovative methods exist for ensuring the trench does not collapse during excavation (e.g., pre-injection of a stabilizing agent).

The continuous trencher is the most applicable trench installation method for the PRB proposed for A-Zone ground water. This method uses a trenching apparatus on a heavy crawler-mounted vehicle to dig a narrow, continuous trench while simultaneously placing the reactive wall material as the trencher advances. This method can install reactive material at a faster rate and is more cost effective, relative to the other trenching methods, but relies on the lack of subsurface obstructions, which result in discontinuities of the wall. This would be the preferred PRB installation method for the Hookston Station Parcel, but may be determined to be infeasible due to the extent of subsurface utilities.

The other PRB installation method that would be further examined for the proposed A-Zone PRB is direct injection of zero-valent iron. Direct injection has been performed using several methods, some of which are proprietary methods specific to individual contractors. The primary direct injection methods reviewed during this FS are hydraulic fracturing

and jetting. These methods involve injecting iron alone in a powder or granular form or a mixture of iron and a biodegradable substrate of gel or slurry. The material is injected at a high pressure to either create fractures that are filled with the injected iron mixture (hydraulic fracturing) or to erode the subsurface soil enough to mix the injected iron with the soil (jetting). These installation methods are less likely to be affected by subsurface utilities than traditional trenching methods. Methods exist for verifying that the injection has created a continuous “trench”.

Following completion of the PRB bench testing and initial design of the PRB, contractors and installation methods would be investigated further to determine the most appropriate and cost-effective method for installation. Further discussion of the components and procedures of the selected installation method would be incorporated into the final design documents.

8.3.2 *B-Zone Chemical Oxidation*

The chemical oxidation component of the preferred remedial alternative provides for localized treatment of high concentration TCE in B-Zone ground water to prevent TCE from migrating vertically or further downgradient. Chemical oxidation is an effective remedy for destruction of TCE under appropriate conditions. These conditions include low concentrations of non-contaminant oxidizable material and hydraulic conditions that allow injection of appropriate volumes of solution to achieve distribution and interaction of the oxidant with the chemicals of concern. Results of the chemical oxidation pilot study would be used to refine quantities and locations for the delivery of the oxidant solution. This section provides a description of the preliminary plan for performance of chemical oxidation in B-Zone ground water at the Hookston Station Parcel.

The chemical oxidation component of the preferred remedial alternative involves direct-push injection of a dilute solution of potassium permanganate. Common direct-push injection equipment, including direct-push drilling rig, mixing system with tank and mixer, injection pumps, and piping, hoses, and valves would be assembled and mobilized to the Hookston Station Parcel. All equipment would be constructed of materials resistant to the permanganate oxidant.

Solid potassium permanganate would be mixed at the Hookston Station Parcel with tap water to a concentration of approximately 3 percent by weight. Following mixing, the oxidant solution would be injected into standard direct-push boreholes from the top of the B-Zone (approximately 50 feet bgs) to the bottom depth of the B-Zone (approximately 70 feet bgs)

in the impacted area shown on Figure 6-7. A volume of approximately 560 gallons of oxidant solution would be injected at each of the 150 injection points spaced across the impacted area. The 560-gallon volume of 3-percent solution contains approximately 143 pounds of potassium permanganate. These quantities may be adjusted based on the results of the pilot study.

Several of the injection points would be installed at the perimeter of the 199 Mayhew Way building. In order to provide additional treatment under the building, direct-push borings would be installed at a slight angle toward the center of the building, resulting in injection of the oxidant solution further under the building.

The chemical oxidation proposed for B-Zone ground water would consist of repeating the injections described above over three separate injection events.

8.3.3 *Vapor Intrusion Prevention Systems*

The existing residential indoor air risks associated with vapor intrusion of TCE in ground water within the downgradient study area (discussed in Section 2.3.2) would be addressed through vapor intrusion prevention systems designed specifically for the residence being addressed.

Implementation of the systems would consist of installation of a vapor barrier on the soil under residences to prevent migration of vapor up into the residence. Under the vapor barrier, low flow vapor extraction would be performed as an enhancement to the vapor barrier. The low flow extraction would enhance the removal of TCE and degradation products from soil vapor. Annual maintenance or inspection of the system components would also be performed.

8.3.4 *Private Well Removal*

The existing private irrigation wells located at residences within the downgradient study area are proposed to be decommissioned as a component of the preferred remedial alternative. The wells are currently only used for irrigation and/or filling of swimming pools. Following removal of the wells, the components that were plumbed to the well would be connected to the existing public water supply connection for the house.

The procedures for decommissioning the private wells would be outlined in the Remedial Design, following a survey of the locations and specifications for each of the wells. These factors would dictate how the

wells would be decommissioned and the level of effort required to connect the irrigation/swimming pool systems that were previously fed by the wells.

8.3.5 *Land Use Restrictions and Institutional Controls*

Land use restrictions would be implemented for the neighborhood located within the mixed ground water plume area according to guidelines set forth by regulatory agencies and State and local governments. The land use restrictions would ensure that current and future landowners are not permitted to install water supply wells until the final ground water cleanup goals are achieved (Table 4-5).

In addition, the SMP would be developed as a component of the restrictions, requiring current and future landowners of the Hookston Station Parcel to follow the guidelines that it provide for the handling and off-site disposal of a small quantity of subsurface soil that may contain elevated concentrations of arsenic that may pose a risk to construction workers.

8.4 *EFFECTIVENESS MONITORING*

This section describes the monitoring proposed to evaluate the effectiveness of the remedial action at achieving RAOs. Ground water monitoring would evaluate the direct effectiveness of the PRB and chemical oxidation for destroying VOCs in the respective treatment zones, as well as evaluate the ability of natural degradation processes to reduce VOCs. In addition, air quality monitoring would be performed to ensure effectiveness and completeness of the vapor intrusion prevention.

8.4.1 *Ground Water Monitoring*

To ensure ground water RAOs are achieved, water quality monitoring would be conducted as a component of the preferred remedial alternative. Ground water monitoring would be conducted periodically and samples would be analyzed for the same parameters as the proposed baseline sampling (Section 8.1.1). The proposed monitoring schedule utilizes a regressive sampling frequency to provide closely spaced data during the initial several years following completion of the remedial actions, followed by less frequent monitoring to ensure completion of treatment and shrinking of the A- and B-Zone ground water plumes. The proposed monitoring schedule for the A-Zone is as follows:

- Quarterly sampling during years 1 through 5;

- Semi-annual sampling during years 6 through 10; and
- Annual sampling for years 11 through 30.

The proposed chemical oxidation for B-Zone ground water on the Hookston Station Parcel is expected to result in a more rapid reduction of VOC ground water concentrations compared to the proposed remedial action for the A-Zone. Therefore, the following monitoring schedule is proposed for the B-Zone:

- Quarterly sampling during years 1 through 3;
- Semi-annual sampling during years 4 through 7; and
- Annual sampling for years 8 through 30.

With the approval of the RWQCB, the duration of sampling may be shortened or lengthened based upon the performance of the remedial systems.

8.4.2 *Indoor Air Monitoring*

To ensure effectiveness of the vapor intrusion prevention systems installed in residences within the downgradient study area, annual indoor air sampling would be conducted. Vapor samples would be collected and analyzed for VOCs using the currently employed methods. Similar to the construction of the vapor intrusion prevention systems, the sampling protocol for the homes would be designed based on the construction method and layout of each home.

In addition to annual sampling at residences where vapor intrusion prevention systems have been installed, homes within the area of current A-Zone TCE concentrations above the ground water screening value (530 µg/L for prevention of residential indoor air impacts) would be included in the annual indoor air sampling schedule. This sampling would allow determination of the need to expand the network of vapor intrusion prevention systems. The length of time necessary to continue the indoor air monitoring program would be determined based on ground water, soil vapor, and indoor air data trends observed within the initial 5 years of construction of the PRB. These data would be evaluated annually, and recommendations for modifications to the monitoring frequency would be made as appropriate. The success of these systems is dependent on private property access and cooperation with individual impacted residents.

IMPLEMENTATION SCHEDULE

A preliminary schedule for the components of this Implementation Plan is shown in Table 8-1. This schedule is subject to change based on the progress of individual components and other implementation issues. Some of the tasks can be performed concurrently. A more comprehensive construction schedule would be provided in the Remedial Design, which would be prepared following approval of the FS.

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